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User Manual for CSP_VANA: A Check Standards Measurement and Database Program for Microwave Network Analyzers

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User Manual for CSP_VANA: A Check Standards Measurement and Database Program for Microwave Network Analyzers

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Abstract

Vector network analyzers are a convenient way to measure scattering parameters of a variety of microwave devices. However, these instruments, unlike oscilloscopes for example, require a relatively high degree of user knowledge and expertise. Due to the complexity of the instrument and of the calibration process, there are many ways in which an incorrect measurement may be produced. The Microwave Project, which is part of SNL's Primary Standards Laboratory, routinely uses check standards to verify that the network analyzer is operating properly. In the past, these measurements were recorded manually and, sometimes, interpretation of the results was problematic. To aid our measurement assurance process, a software program was developed to automatically measure a check standard and compare the new measurements with an historical database of measurements of the same device. The program acquires new measurement data from selected check standards, plots the new data against the mean and standard deviation of prior data for the same check standard, and updates the database files for the check standard. The program is entirely menu-driven requiring little additional work by the user. This report describes the function of the software, including a discussion of its capabilities, and the way in which the software is used in our lab.

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1. INTRODUCTION

Vector network analyzers are widely used instruments that measure the scattering parameters or S-parameters of a variety of microwave devices. Typical devices that are measured include attenuators, terminations, mismatches, shorts, and directional couplers. S-parameters are complex quantities which define the ratios of reflected and transmitted traveling waves measured at the ports of the network analyzer test sets. Network analyzers require a relatively high degree of user knowledge and expertise and, due to the complexity of the instrument and of the calibration process, poor measurements can be made. Network analyzers must be calibrated* prior to obtaining any measurements. The measurement calibration or error correction produces a set of error terms from the measurements of known calibration devices (such as shorts, opens, and loads); these error terms are used to mathematically eliminate errors when a device is measured. Clearly, a poor measurement calibration of the instrument will give erroneous results.

To eliminate the potential calibration problem and also to insure the highest quality measurement of microwave devices in the Primary Standards Laboratory at Sandia National Laboratories, we have developed a computer program that acquires measurements of check standards and maintains a database of these measurements [1,2]. Many laboratories have used check standards to monitor the proper operation of a measurement system and ensure that the measurement process is under statistical control [3]. This report provides a user manual for the use of the computer program that allows a user to check the measurement system, keep a record of these measurements, and maintain an historical database of the measurements.

The check standards database program described here may be used with either an HP 8753 or HP 8510 Network Analyzer [4]. The program itself is written in HP Basic to maintain compatibility with the different systems used in our lab. The program can acquire new measurement data from selected check standards, plot the new data against the mean and standard deviation of prior data for the same check standard, and update the historical database files for the check standard.

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* *The term "calibrated" here refers to using the calibration kit for the network analyzer to set up the instrument and does not represent a true calibration (in the sense of what a standards laboratory might do to estimate the errors in a measurement) of the network analyzer.*

The program may be run stand-alone or loaded as a subprogram to a Basic program already in memory. The software was designed to require little additional effort on the part of the user. To facilitate this design goal, the program is entirely menu-driven. In addition, the user is not required to remember file names or directories since this is handled by the software. However, the user does have control of file names and parameters within a definition file which sets up the basic scheme of file names.

The software also acts as a database manager allowing the user to add or delete records from the database. The database files are DOS text files and, therefore, allow for relatively easy editing or importing into other applications such as spreadsheet programs.

In the Microwave Project, we use the software to maintain a database of essentially twenty check standards (some may be the same device but used for a different type of measurement) in four connector types: N, APC-7, APC-3.5, and GR-900. New devices and connector types may easily be added. The software can produce plots of magnitude or phase angle vs. frequency or an historical plot of device measurements at a single frequency. If desired, both magnitude and phase data for a device may be saved and plotted.

The software is compatible with HP BASIC (Version 5.13 or higher) and with TransEra HTBasic for DOS (Version 4.1 or higher) or WINDOWS. When run using HP BASIC, a Basic Language Processor card must be installed in the computer in order to acquire new measurement data. With HTBasic, an IEEE-488 interface card is necessary. However, the database files may be accessed without any interface card - with the restriction, of course, that new data cannot be acquired.

2. LOADING AND RUNNING THE PROGRAM

The Check Standards and Database Program for Vector Automatic Network Analyzers (*CSP_VANA)* is designed to be user friendly and easy to use. This section describes how to load the program and gives a short example of its use to measure a check standard to verify proper operation of a supported network analyzer. In addition, the hardware requirements for the program are also specified.

2.1. Hardware and Software Requirements

To run this program, either HP BASIC Version 5.13 or higher or TransEra HTBasic Version 4.1 or higher is required. HP Basic requires the presence of a Basic Language Processor card in a PC. In order to acquire data from an attached network analyzer, an IEEE-488 interface card is required when running the program under HTBasic. However, the program may still be run without this interface card but only database operations (data display and plotting, record addition or deletion) are allowed.

2.2. Network Analyzers Supported

Vector network analyzers models 8753 and 8510 from Hewlett-Packard [4] are supported in this software. Other network analyzers may easily be added if desired by modification of the VANA I/O subprograms described in Section 4.

2.3. Memory Requirements

The software requires a minimum of 225 kB of memory in order to run after the Basic system has been loaded. With this amount of memory, the user should be able to acquire, plot, and store data from the network analyzer. In order to utilize all database operations and the help display, approximately 430 kB of memory are required.

2.4. Loading the program

It is assumed that the program currently resides in the default directory and that the file name is CSP_VANA.

In the BASIC operating system, the program may be loaded either as a standalone program or as a series of subprograms from some calling program. As a standalone program, simply type LOAD “CSP_VANA” and press Enter. If you want to use the program from within another program, with the other program in memory, execute the command LOADSUB ALL FROM “CSP_VANA.” The calling program must be modified to call the check standard program. With the check standard program already in memory, the program line *CALL Csp_vana*, executed from the calling program, will start the check standard program.

See Section 5 for a summary of the file requirements.

In order to use the check standard program, a directory named *CSP_FILE* must reside on the drive defined by the definition file. In this directory must be the subdirectories (such as HP8753) also defined by the definition file. If the the *CSP_FILE* directory does not exist, the program will display an error message and either stop or return to the calling program.

2.5. Example of Using the Program

It's not necessary to have a network analyzer available. Clearly, if one is not present no new measurements may be obtained. However, the software can still be used to view and/or edit the data in any check standard device's database.

Perhaps the best way to exhibit the capabilities of the software is to show an example of typical use. Suppose that you have a 10 dB Type N attenuator that requires calibration. The first thing you must do is to "calibrate" the network analyzer. After this, the check standards program is loaded and started. When the program is started, it detects the type of network analyzer connected to the computer. First, the software loads the appropriate definition file. The definition file contains the list of check standard devices as a function of connector type and the names of the files for each device. The Main Menu screen, as shown in Figure 2, is now displayed. Since we desire to measure the check standard devices, key *F1, New Meas.*, is selected. This selection brings up the Measurement Menu as shown in Figure 7.

Before any measurements can be taken, the user must select the check standard device. First, the user chooses the connector type by selecting *F5, Select Connectr.* The program displays a list a connector types as shown in Figure 3. After the correct connector type is chosen, the user selects key *F6, Select Standard*, from the Measurement Menu. The list of check standard devices is displayed as shown in Figure 4.

If the user elects to measure the 3 dB attenuator check standard, the program displays the Measurement Menu screen in Figure 9. Now the screen displays the connector type and the check standard selected. To take measurements, key *F1, Acquire Data*, is selected.

At this point, the software obtains the frequency list from the network analyzer, commands the instrument to do a sweep, and , once the sweep is done, acquires the appropriate S-parameter data. Using the file names provided by the definition file, the software obtains the past measurement history from the database files for the selected check standard device. The newly measured data are plotted along with the standard deviations computed from the previous device measurements. An example of this plot is shown in Figure 8.

The data plotted in Figure 8 are not the actual measured values but instead the difference between the measured value and the prior mean value at each frequency. The two curves are the ± 3 standard deviation (3σ) values

calculated from the prior device measurements at each frequency. The solid circles show the current device measurements. Clearly, the user wants the measured values (i.e. the solid circles) to fall between the two 3σ curves. When that happens, the user can safely assume a valid measurement calibration of the network analyzer has been made and subsequent measurements using this measurement calibration will be within established uncertainties.

The plot in Figure 8 also provides useful information regarding the check standard device and the data. The plot title specifies the network analyzer used to take the measurements and the definition of the device (i.e. device type, model, and serial number). The right margin of the plot lists the connector type, the name of the database file that was accessed, the average standard deviation, and the total number of frequencies in the database for this device. Below the number of frequencies, other information is displayed depending on the type of plot. In the case of Figure 8, the plot is of newly acquired data. So the information line states "New Data" and the number of frequencies measured.

The following section describes in more detail the operation of all the menus and operations associated with the softkeys.

3. DESCRIPTION OF MENUS

Since the program is entirely menu-driven, a succinct description of the operation of the program is best found by reviewing each of the menus. When the program is first started or called from another program, it attempts to read a definition file (having a file name extension DEF) from the directory named CSP_FILE on the default drive. Figure 1, shown below, gives an example of the screen when more than one DEF files are available or when no network analyzer is detected by the program. If the CSP_FILE directory does not exist or no files exists within this directory the program stops (or returns control back to the calling program). The format of the DEF file, which is constructed by the user using any ASCII editor, is described in a later section.

Appendix A shows a flow chart illustrating the relationships among all the menus.

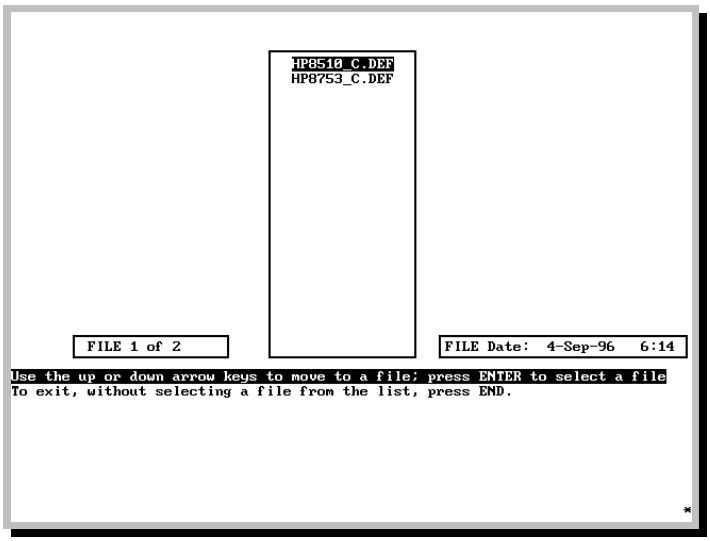


Figure 1. Example of the screen displayed when the program is started. If more than one DEF files are available in the CSP_FILE directory on the default drive, then the list of files is displayed. The user selects the desired file for the specific application.

3.1. MAIN MENU

After a DEF file has been successfully read, the program displays the Main Menu which is shown in Figure 2. The Main Menu provides access to all other menus or functions within the program through the use of the eight softkeys labeled *F1* through *F8* on the keyboard. The operation of each labeled softkey is described below. In addition, from any displayed menu, the user may press Alt-H to display a brief help display for that menu.

☞ *See Section 5.2.5 for further information about the Help display.*

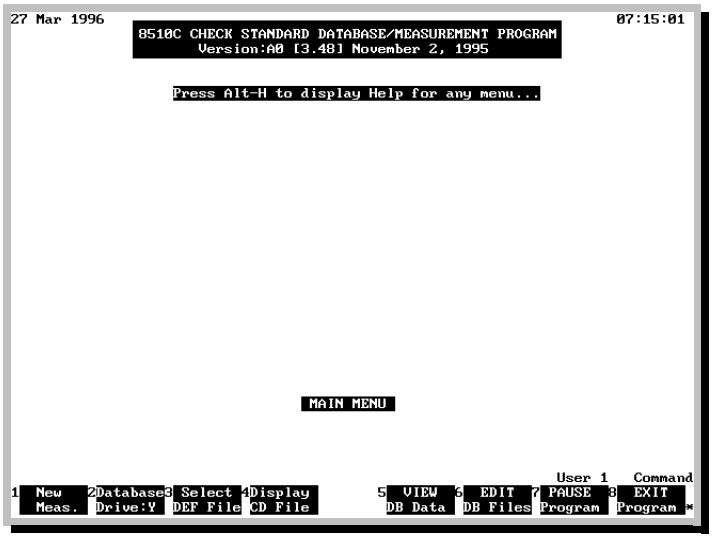


Figure 2. The screen displayed for the Main Menu. The softkeys, labeled *F1* through *F8*, allow the user to control the operation of the program. Some of these softkeys access other menus while the others perform specific functions.

Softkeys are the function keys whose function can be changed by the software. The term softkeys will be used for these keys in this manual.

3.1.1. *F1*: New Meas.

This softkey switches the program to the Measurement Menu which is described in Section 3.2. This menu acquires the measurement data from the network analyzer and plots this data with the mean and standard deviation of prior measurements for the selected check standard. The user can quickly determine if a good measurement of the check standard has been made by viewing this plot.

See Section 3.2.1 and Figure 8a for an example of this type of plot

3.1.2. *F2*: Database Drive: Y

The label for this softkey displays the letter of the drive containing the database files which the program will use. Pressing the key allows the user to select a new drive for the database files. The new drive letter must have a directory named CSP_FILES containing at least one definition file. If it doesn't, the program displays an error message and then returns to the Main Menu. The old drive is retained as are the definitions obtained from the definition file. If the new drive does have the proper directory in place and at least one definition file, then the program checks to see whether the definition file is compatible with the current network analyzer model. For example, suppose the network analyzer connected to the computer is a model HP 8753. If definition files exist for an HP 8753 on the new drive, then these will be displayed. The user may select the desired definition file from the displayed list (see Figure 1). If only one definition file for an HP 8753 network analyzer is present, this file is read. If the available definition files are not available for the connected network analyzer (for example, only definition files for an HP 8510 network analyzer are present), the program will display this list of files. If the user selects one of these files, the program warns the user that the file is not compatible with the attached network analyzer. The program sets a flag within the code that will not allow the user to access the Measurement Menu. However, all other database operations are still available.

3.1.3. *F3*: Select DEF File

Selecting this softkey allows the user to select any definition files present in the CSP_FILES directory. A screen similar to that showed in Figure 1 is displayed. A definition file for an HP 8510 network analyzer may be selected even though an HP 8753 network analyzer is connected to the computer. However, selecting one of these definition files no longer allows the user to obtain new measurements on check standards. To do this, the program must be restarted. However, this option is useful since it allows access to the database for any network analyzer or set of check standards that may be present on the database drive.

3.1.4. *F4*: Display CD File

Control Data (CD) files are DOS ASCII files which contain the measured data for a specific check standard taken at a specific day and time. Selecting this softkey allows the user to display or print a selected CD file. The user is asked to select a connector type and a standard. This is done by displaying the list of connector types first and then the list of standards. The connector types and standards are defined by the definition file that was selected or read when the program was started or that was selected

later by the user. Figure 3 displays the screen showing a list of possible connector types the user may select. After selecting a connector type, a list of check standards for that connector type as defined by the previously selected definition file is displayed. An example of this display is shown in Figure 4.

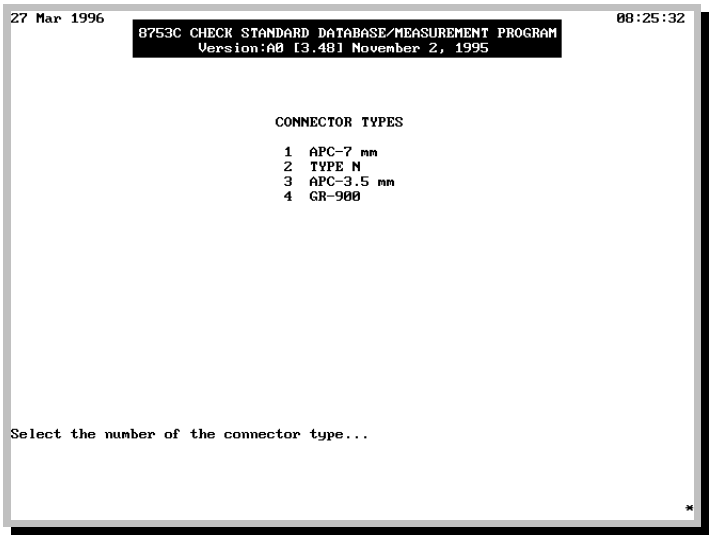


Figure 3. The screen displayed when a connector type must be selected. The list of connector types is defined by the particular definition file selected.

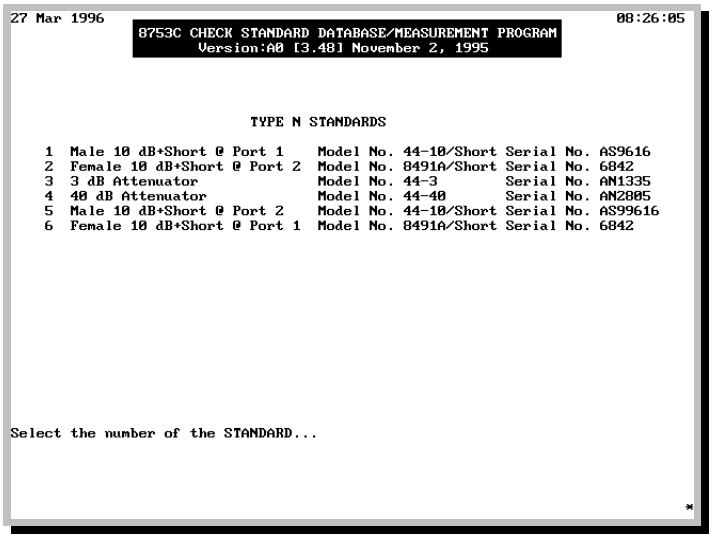


Figure 4. The screen displayed when a standard must be selected. The list of check standards depends on the connector type selected and is defined by the definition file.

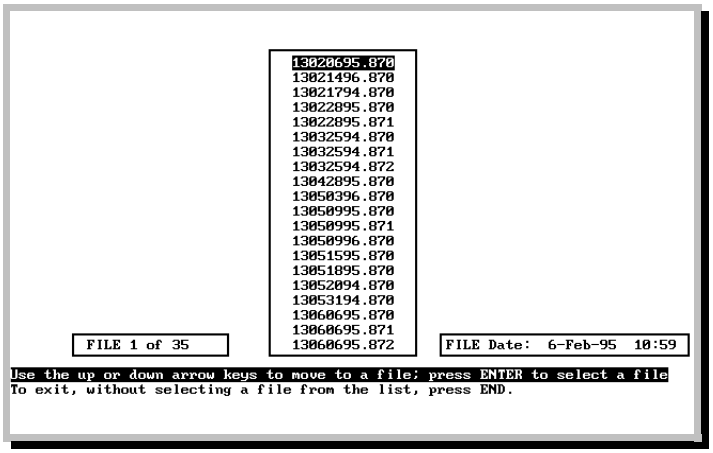


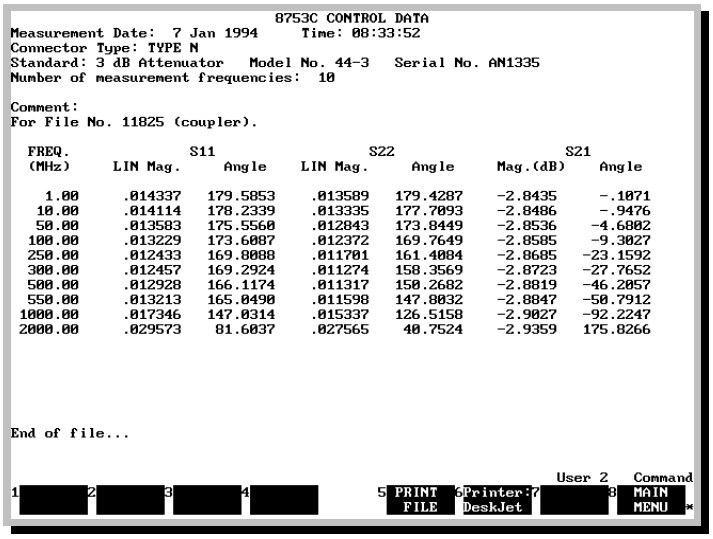
Figure 5. Example of a list of CD files available for display on the database drive. The user moves to the desired file using the arrow keys and selects the file using the Enter key.

After the connector type and check standard have been selected, the program displays a list of files matching the selected connector type and check standard device. An example of such a display is shown in Figure 5. The arrow keys are used to move through this list and the user selects a file by highlighting the desired file name and pressing the Enter key. The naming convention and structure used for these files is described in Section 5.2.4. If a file is selected, its contents are displayed as shown in Figure 6. The user may elect to produce a hard copy of this file on the selected printer by pressing softkey *F5*. The softkey *F8* returns the user to the Main Menu.

Printer selection is more fully described in Section 3.5, Copy Menu

3.1.5. *F5*: VIEW DB Data

This softkey transfers the user to the View Menu which is described in Section 3.3. Briefly, the View Menu allows the user to display, either by a plot or a table, the data contained within the database for a particular check standard. The database files are more fully described in Section 5.2.



```
                              8753C CONTROL DATA
Measurement Date:  7 Jan 1994      Time: 08:33:52
Connector Type: TYPE N
Standard: 3 dB Attenuator   Model No. 44-3   Serial No. AN1335
Number of measurement frequencies:  10

Comment:
For File No. 11825 (coupler).

  FREQ.              S11                 S22                 S21
  (MHz)     LIN Mag.      Angle    LIN Mag.      Angle     Mag.(dB)    Angle

    1.00      .014337   179.5853    .013589   179.4287    -2.8435     -.1071
   10.00      .014114   178.2339    .013335   177.7093    -2.8486     -.9476
   50.00      .013583   175.5560    .012843   173.8449    -2.8536    -4.6802
  100.00      .013229   173.6087    .012372   169.7649    -2.8585    -9.3027
  250.00      .012433   169.8088    .011701   161.4084    -2.8685   -23.1592
  300.00      .012457   169.2924    .011274   158.3569    -2.8723   -27.7652
  500.00      .012928   166.1174    .011317   150.2682    -2.8819   -46.2057
  550.00      .013213   165.0490    .011598   147.8032    -2.8847   -50.7912
 1000.00      .017346   147.0314    .015337   126.5158    -2.9027   -92.2247
 2000.00      .029573    81.6037    .027565    40.7524    -2.9359   175.8266




End of file...

                                                                  User 2   Command
1        2        3        4        5 PRINT  6Printer:7        8 MAIN
                                      FILE     DeskJet          MENU
```

Figure 6. Example of the contents of a CD file.

3.1.6. *F6*: EDIT DB Files

This softkey calls the Edit Database Menu which is described in Section 3.4. This menu allows the user to delete a record from the database file, add new data contained in a CD file, update a selected database file, or sort by measurement date a selected database.

3.1.7. *F7*: PAUSE Program

This softkey pauses the program within the MAIN context. It is used for program debugging when the value of a variable must be checked. Pressing the Continue softkey will resume the program in the MAIN Menu.

3.1.8. *F8*: EXIT Program

Selecting this softkey ends the CSP_VANA program. If the program had been called from another program, then control is returned to the calling program. Otherwise, the program stops. In either case, before the program finishes, all the files in the current DB_FILES subdirectory are set to read only. This is done as a precaution to prevent any inadvertent deletion or modification of these files.

3.2. MEASUREMENT MENU

The initial Measurement Menu screen is shown in Figure 7. When a connector type or check standard is selected, the appropriate information is displayed on the screen. The S-parameters measured depend on the check standard selected. Typically, for two-port devices such as attenuators, all S-parameters (really, only S_{11}, S_{22}, and S_{21}) are measured. For one-port devices, the S-parameter measured depends on the port defined for that check standard in the definition file. The functions of the labeled softkeys are described below.

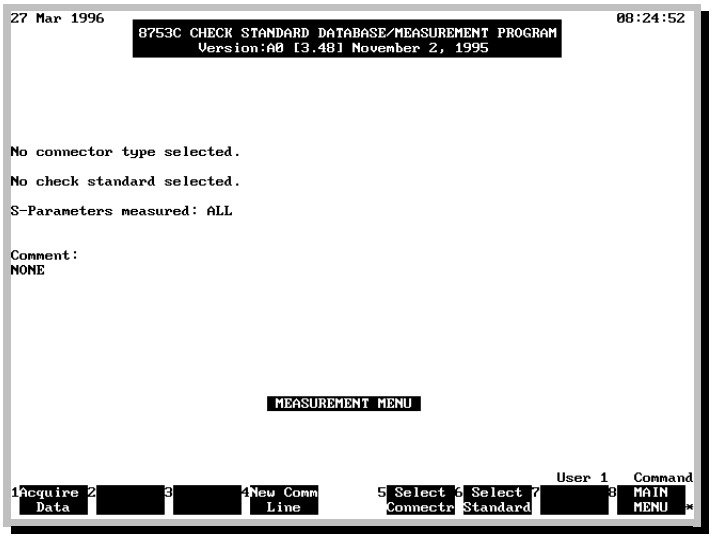


Figure 7. The initial screen displayed when the Measurement Menu is selected from the Main Menu. The user must select both a connector type and a check standard before any measurement data may be acquired.

3.2.1. *F1*: Acquire Data

Selecting this softkey directs the program to command the connected network analyzer to begin a measurement. When the measurement has completed, the appropriate S-parameter data is transferred to the computer. The program then reads the information from the summary (SUM) file for the selected check standard. The new measured data is then plotted along with the mean and three times the standard deviation calculated from previous measurements of the check standard. An example of such a plot is shown in Figure 8a.

The program requires that the user select a check standard before acquiring any data. If a check standard has not been selected or if no network

When data are plotted from the Measurement Menu, F8 will return the program back to that menu. When data are plotted from the VIEW Menu, F8 returns to the VIEW Menu.

Solid circles show the measurement data. An open circle indicates data at a new frequency for the database; i.e. no previous measurement exist at that frequency. Small open squares on the standard deviation lines denote frequencies having only one measurement. The program uses the standard deviation at the previous frequency in this case.

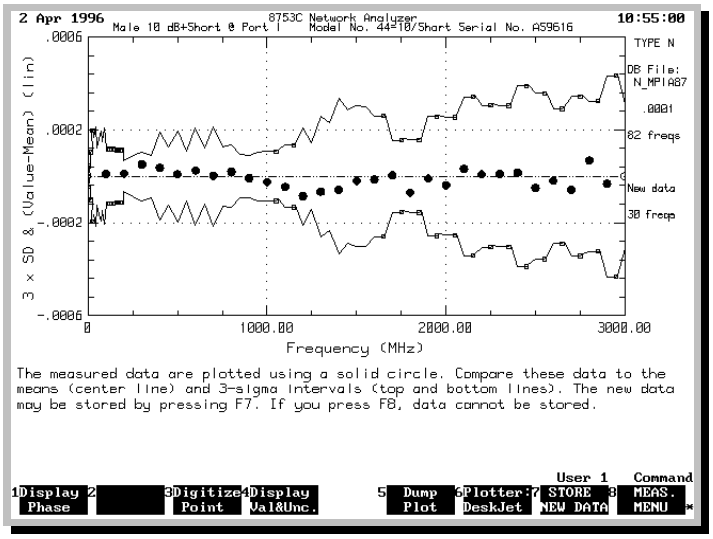


Figure 8a. Example of a plot of newly measured data displayed with the means and standard deviations for the selected check standard. The user can compare the new data with the mean and standard deviation to determine whether a good measurement has been made. The data displayed came from a one-port device; both the magnitude and the phase data are used to compare the new measurements with the means and standard deviation.

These softkeys are called the Store Menu in Appendix A.

Figure 8b. The softkey definitions displayed when the STORE NEW DATA softkey (*F7*) is selected as shown in Figure 8a. Softkey *F5* will store the newly acquired data in a CD file but will not update the database or summary files. Softkey *F7* stores the new data in a CD file and updates the database and summary files. New mean values and standard deviations are calculated.

analyzer is connected to the computer, an error message is displayed when the user selects this softkey.

The menu displayed when data are plotted is called the Copy Menu. Generally, it allows the user to make a hard copy of the plot on a selected device. Certain softkeys have different definitions depending upon the type of check standard data displayed. The functions of these softkeys are described in Section 3.5. Softkey *F7* is only defined within the Copy Menu when new data is acquired from the network analyzer. When it is depressed, the softkey definitions change to that shown in Figure 8b.

3.2.2. *F4*: New Comm Line

This softkey allows the user to enter a comment that is stored with the CD file. An example of a CD File is shown in Figure 6.

3.2.3. *F5*: Select Connector

This softkey displays the list of connector types as defined by the definition file. An example of this display is shown in Figure 3.

3.2.4. *F6*: Select Standard

This softkey displays the list of check standards as defined by the definition file. An example of this display is shown in Figure 4. If the user presses this softkey before selecting a connector type, the program displays an error message instructing the user to select a connector type before a check standard device can be selected.

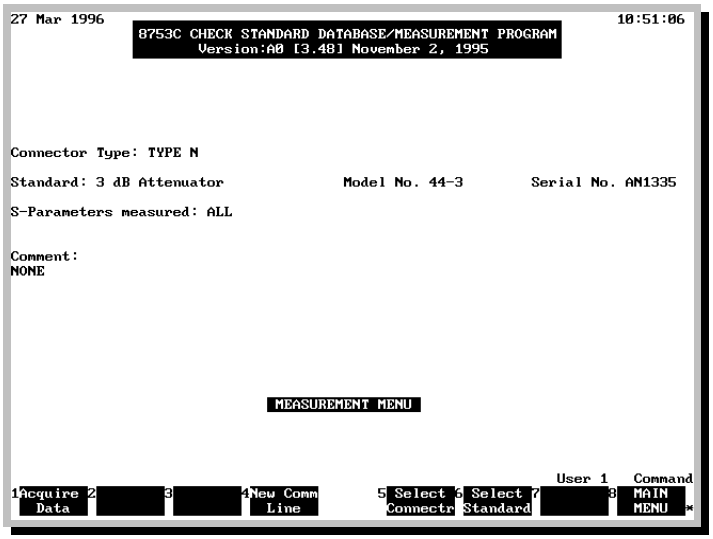


Figure 9. Example of the Measurement Menu display after a connector type and check standard device have been selected.

When the user has selected both a connector type and a check standard device, the Measurement Menu displays the selections as shown in Figure 9.

3.2.5. *F8*: MAIN MENU

This softkey returns the user to the Main Menu.

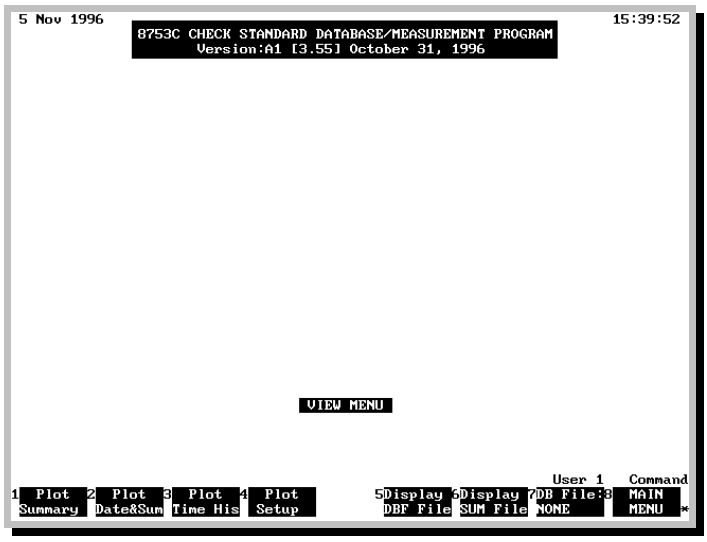


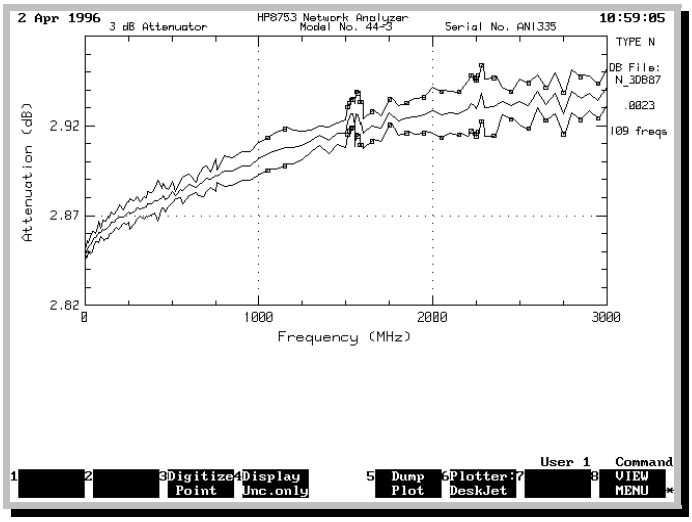
Figure 10. The initial screen displayed when the View Menu is selected from the Main Menu. The user may select any softkey after a database file (defined by the connector type and standard) has been selected using softkey *F7*.

3.3. VIEW MENU

The View Menu allows the user to plot the contents of selected database files or to list either the records in a DBF file or the data within a SUM file. The initial menu displayed when the View Menu is selected is shown in Figure 10. The functions performed by each of the listed softkeys is described below. Note that a database file, as defined by the connector type and check standard, must be selected using softkey *F7*. If a file has not been selected before any of the other softkeys are selected, the program cautions the user that no file has been selected and returns to the View Menu.

3.3.1. *F1*: Plot Summary

This softkey plots the summary data (contained in the SUM file) for the selected check standard. The mean value of the data at all measured frequencies is plotted. In addition, two other lines are plotted. First, three times the calculated standard deviation is added to the mean value at each frequency. Second, three times the calculated standard deviation is subtracted from the mean value at each frequency. These two lines provide the bounds or the control limits on the measurements of the check standard. Figure 11 shows such a plot for a Type N 3 dB attenuator. After the data is plotted, the Copy Menu is displayed. In addition to the usually defined softkeys (i.e. *F5*, *F6*, and *F8*), softkey *F4* is defined with a label and softkey *F1* is defined for 1-port devices. Two different types of plots



The softkeys F3, F5, F6, and F8 are explained in Section 3.5 on the Copy Menu.

Figure 11. Example of Type N 3 dB attenuator data plotted from the selected SUM file. Here, the mean values and uncertainties are plotted.

may be displayed and these are toggled by using *F4*. In Figure 11, *F4* has the definition **Display Unc.only**. Selecting this key produces a new plot that displays only the uncertainty values. That is, the actual measured values are not displayed but rather the difference between the mean values is shown. The mean value at each frequency is set to zero, and the plus and minus three times the standard deviation values are plotted. This plot removes the curvature from the plotted data due to the frequency dependence of the device. An example of this plot, for the same data as is plotted in Figure 11, is shown in Figure 12. Softkey *F4* is now labeled **Display Val&Unc.** Selecting this key will reproduce the plot shown in Figure 11.

For 1-port devices, the Copy Menu defines softkey *F1* to allow a plot of the phase angle of the device. For 1-port check standards, the software stores and plots both the measured magnitude and the phase angle. Figure 13 and Figure 14 show magnitude plots for a Type N 1-port check standard for the value and uncertainty and the uncertainty only. Figure 15 and Figure 16 show the corresponding plots of the phase angle for the same device.

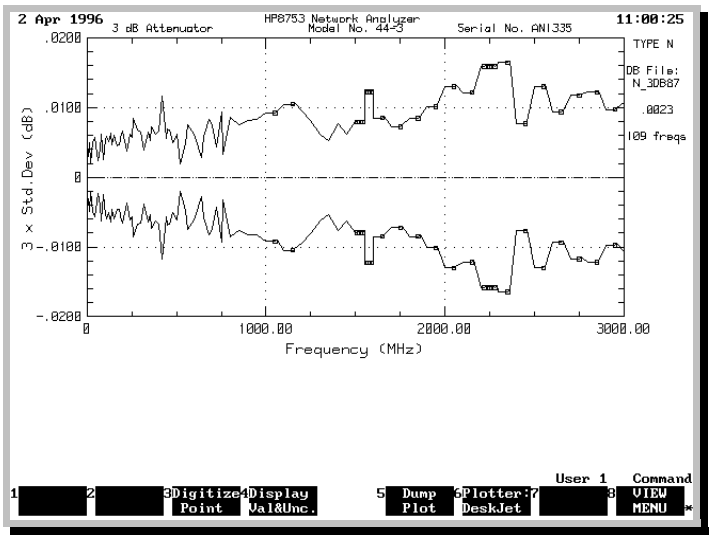


Figure 12. Example of Type N 3 dB attenuator data plotted from the selected SUM file. Here, the difference from the mean values at each frequency are plotted.

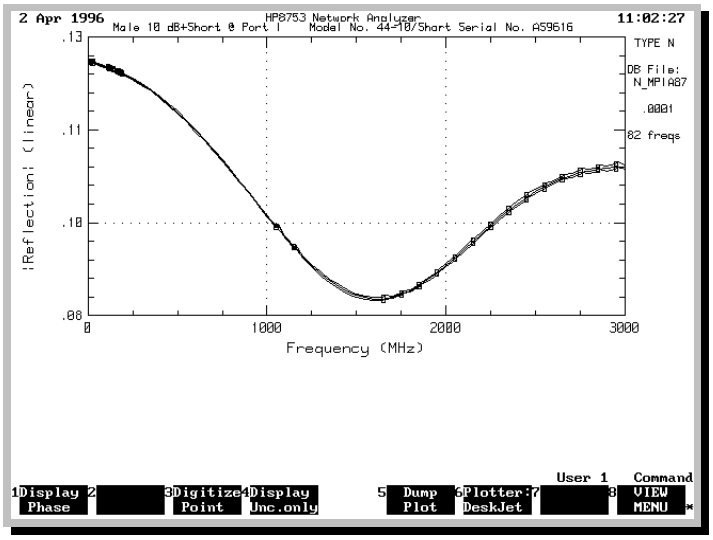


Figure 13. Example of Type N Male mismatch magnitude data plotted from the selected SUM file. Here, the mean values and uncertainties are plotted.

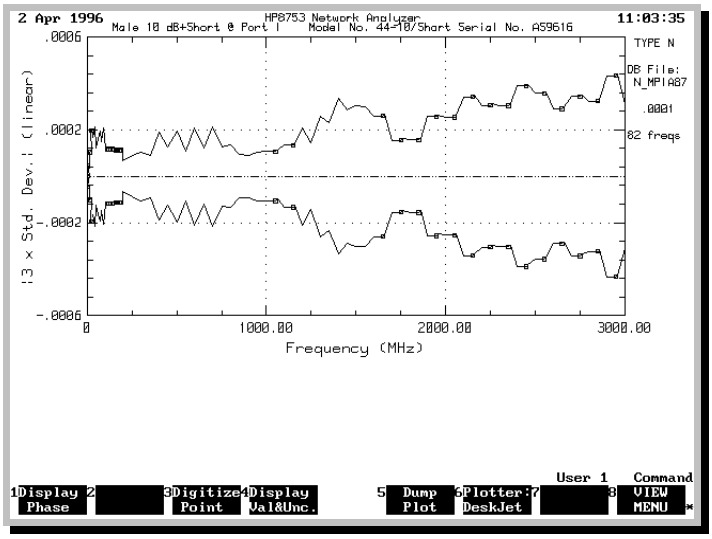


Figure 14. Example of Type N Male mismatch magnitude data plotted from the selected SUM file. Here, the difference from the mean values at each frequency are plotted.

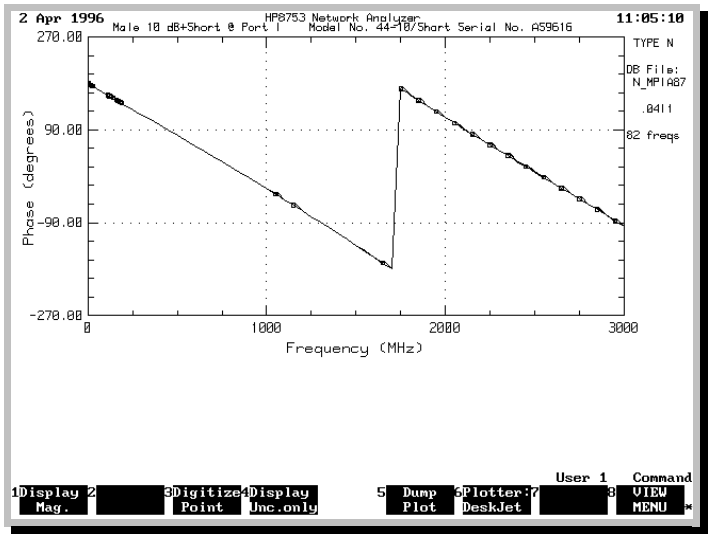


Figure 15. Example of Type N Male mismatch phase angle data plotted from the selected SUM file. Here, the mean values and uncertainties are plotted.

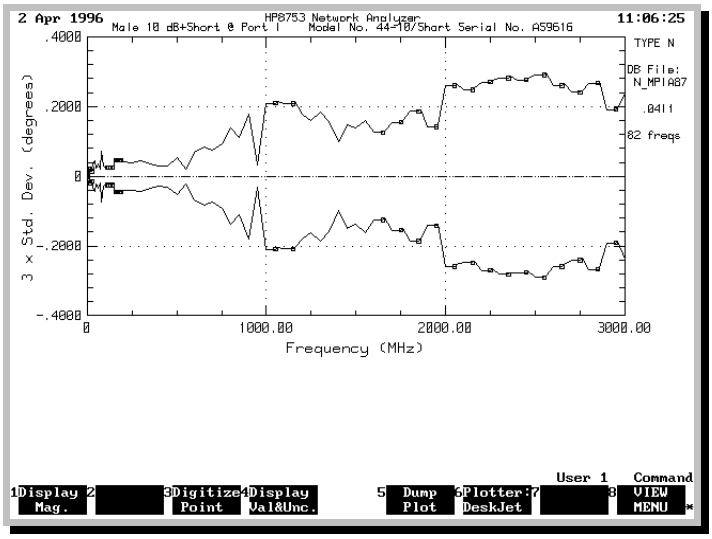


Figure 16. Example of Type N Male mismatch phase angle data plotted from the selected SUM file. Here, the difference from the mean values at each frequency are plotted.

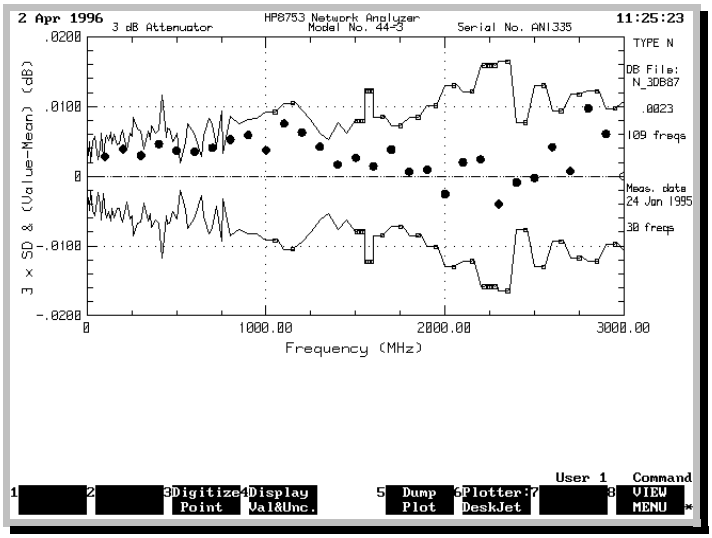


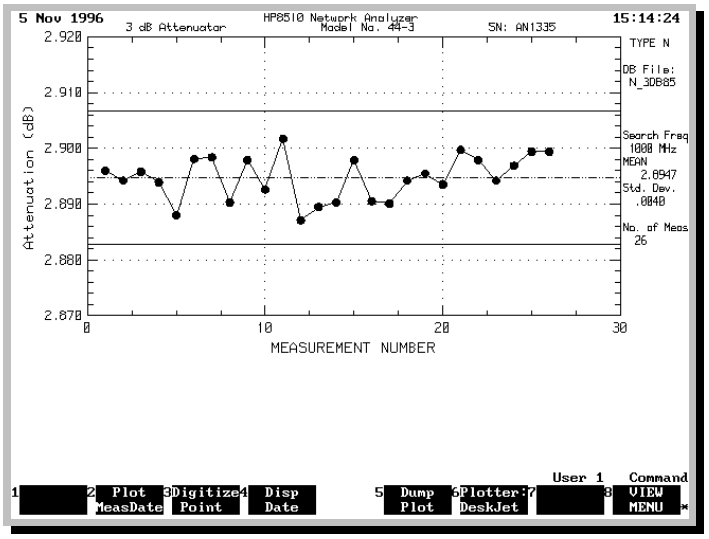
Figure 17. Example of a plot showing the means and standard deviations with the data from one record plotted as discrete points. The measurement date and the number of frequencies in the individually plotted data are displayed in the center right of the plot.

3.3.2. *F2*: Plot Date&Sum

This softkey allows the user to plot the data from a selected record in the DBF file as separate points on the plot of the means and standard deviations for a particular check standard. Figure 17 shows an example of such a plot. The circles are the data from the selected record. Each data measurement stored in the database (DBF) file are measurements stored at separate times. The user may select a measurement taken at a specific time by specifying the appropriate record number. The program prompts the user for the record number containing the data to plot. If the user is unsure about which record number to select, pressing the *Enter* key lists the records in the file. This list is identical to the list produced by the *F5* softkey in the View Menu.

3.3.3. F3: Plot Time His

Selecting this menu item allows the user to view the time history of the check standard at a specific frequency. When this key is selected, the program requests a frequency. After the user enters the desired frequency, the program checks all records in the database (DBF) file for occurrences of this frequency. If the frequency is found in more than one record, the program displays the data with bounds defined by three times the standard deviation. An example of this display is shown in Figure 18. This function shows the user how the measurements on the device at one frequency change over time. The horizontal axis shows the measurement number, that is, the number of times measurements were taken at the selected frequency. Note that the Copy Menu is once again displayed but now softkey *F4* has the definition **Disp Date**. Pressing this softkey directs the program to display the measurement date for a selected measurement number. In addition, for one port devices, softkey *F1* is once again defined to allow the user to toggle between the magnitude and angle displays. When this key is selected, the program must again search through the database file to find the new data (either the phase angle or the magnitude - depending upon what is displayed) at the frequency of choice. Figure 19 shows the same data as in Figure 18 but now plotted as a function of the measurement date.



The measurement number is the sequential number of occurrence of data at the specified frequency within the database.

Figure 18. Example of a time history plot. The mean value is shown by the dashed line in the center. The solid lines above and below the mean are three times the standard deviation. The right side of the screen shows the search frequency, the mean and standard deviation, and the number of measurements at the search frequency. The measured value is plotted vs. the measurement number.

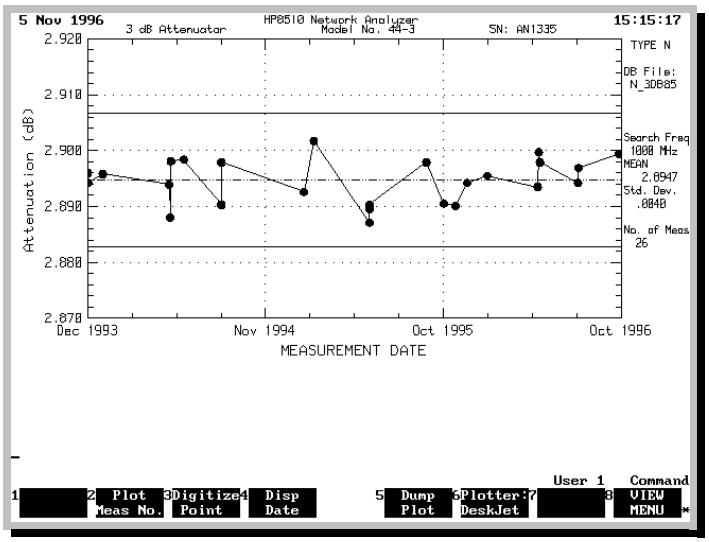


Figure 19. Time History plot where the data are plotted as a function of the measurement date. This is the same data as that plotted in Figure 18.

3.3.4. *F4*: Plot Setup

This softkey displays a menu that allows the user to modify the frequency axis and the y-axis for the Plot Summary display. An example of the screen displayed is shown in Figure 20. The softkeys defined here allow the user to modify the minimum and maximum frequency and y-axis values used in the plot. After the user changes any of the values, returns to the View Menu, and selects the *F1* softkey, the new axes limits will be used to plot the data. The user may use this option to magnify a portion of the data to observe in greater detail how the data may change. The new frequency limits are used in all plots (except the time history plots) until new limits are set or a new check standard is selected. The Y-axis limits cannot be adjusted in the difference plots, however, the frequency limits may be changed.

3.3.5. *F5*: Display DBF File

This selection displays all the records in the database (DBF) file. Each record in the file is stored on a separate line. The length of each record is not fixed and depends on the type of device and the number of measurement frequencies. Section 5 describes the format of these files in greater detail. An example of this display is shown in Figure 21. The program lists the record number, measurement date and time, the number

For 1-port devices, linear magnitude and phase angle are shown. For 2-port devices (attenuators) only the magnitude in dB is displayed.

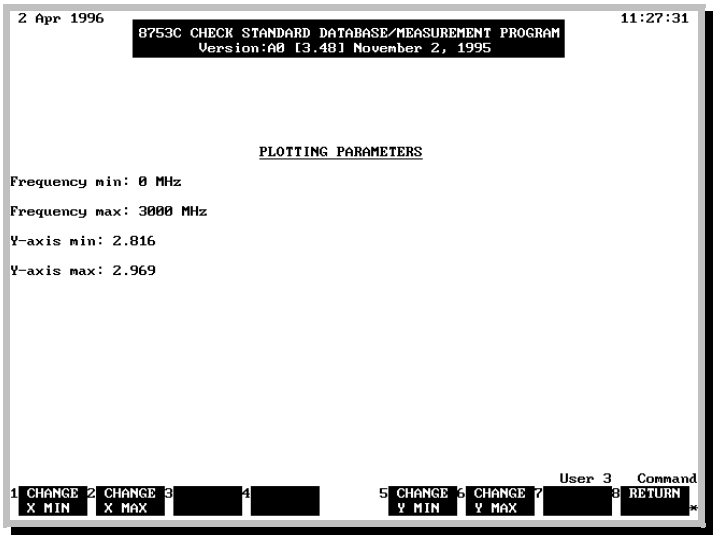
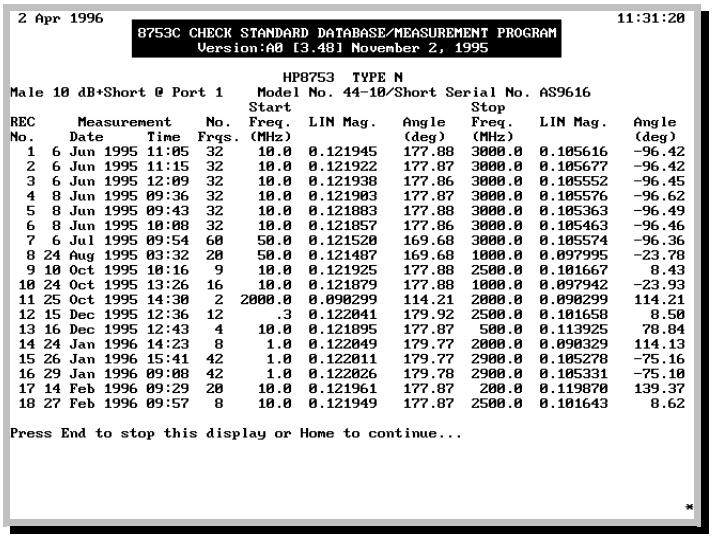


Figure 20. The Plotting Parameters menu screen. The user may select new values for the frequency and y-axis limits on the plots. The new frequency limits remain in effect until changed by the user or when a new check standard file is accessed. Softkey *F8* **RETURN** is used to return to the View Menu.



```
 2 Apr 1996                                                          11:31:20
                  8753C CHECK STANDARD DATABASE/MEASUREMENT PROGRAM
                        Version:A0 [3.48] November 2, 1995

                                    HP8753  TYPE N
Male 10 dB+Short @ Port 1     Model No. 44-10/Short Serial No. AS9616
                                   Start                          Stop
REC      Measurement      No.    Freq.   LIN Mag.    Angle      Freq.    LIN Mag.    Angle
No.      Date     Time   Frqs.   (MHz)               (deg)      (MHz)                (deg)
  1   6 Jun 1995 11:05    32      10.0   0.121945    177.88    3000.0   0.105616    -96.42
  2   6 Jun 1995 11:15    32      10.0   0.121922    177.87    3000.0   0.105677    -96.42
  3   6 Jun 1995 12:09    32      10.0   0.121938    177.86    3000.0   0.105552    -96.45
  4   8 Jun 1995 09:36    32      10.0   0.121903    177.87    3000.0   0.105576    -96.62
  5   8 Jun 1995 09:43    32      10.0   0.121883    177.88    3000.0   0.105363    -96.49
  6   8 Jun 1995 10:08    32      10.0   0.121857    177.86    3000.0   0.105463    -96.46
  7   6 Jul 1995 09:54    60      50.0   0.121520    169.68    3000.0   0.105574    -96.36
  8  24 Aug 1995 03:32    20      50.0   0.121487    169.68    1000.0   0.097995    -23.78
  9  10 Oct 1995 10:16     9      10.0   0.121925    177.88    2500.0   0.101667     8.43
 10  24 Oct 1995 13:26    16      10.0   0.121879    177.88    1000.0   0.097942    -23.93
 11  25 Oct 1995 14:30     2    2000.0   0.090299    114.21    2000.0   0.090299    114.21
 12  15 Dec 1995 12:36    12        .3   0.122041    179.92    2500.0   0.101658     8.50
 13  16 Dec 1995 12:43     4      10.0   0.121895    177.87     500.0   0.113925    78.84
 14  24 Jan 1996 14:23     8       1.0   0.122049    179.77    2000.0   0.090329    114.13
 15  26 Jan 1996 15:41    42       1.0   0.122011    179.77    2900.0   0.105278    -75.16
 16  29 Jan 1996 09:08    42       1.0   0.122026    179.78    2900.0   0.105331    -75.10
 17  14 Feb 1996 09:29    20      10.0   0.121961    177.87     200.0   0.119870    139.37
 18  27 Feb 1996 09:57     8      10.0   0.121949    177.87    2500.0   0.101643     8.62

Press End to stop this display or Home to continue...
```

Figure 21. Example of the display of the contents of a database (DBF) file. In this case, data for a Type N 1-port device is shown. For 1-port devices, both the linear magnitude and phase angle are listed. For two port devices (usually attenuators) only the magnitude, in dB, is displayed.

of measurement frequencies, and the first and last frequency in the record along with the corresponding measured value.

3.3.6. *F6*: Display SUM File

This selection lists on the screen all the frequencies, the mean values, and standard deviations of the measurements from the summary (SUM) file for the selected check standard. Section 5 provides more details about the summary files. Figure 22 shows an example of the display of a summary file.

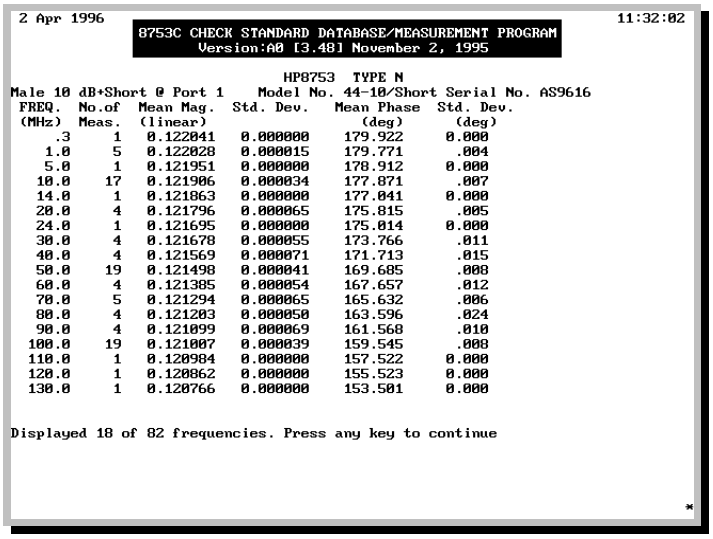
3.3.7. *F7*: DB File: NONE

This softkey allows the user to select the check standard database files that are used in the other selections in the View Menu. Screens similar to those shown in Figure 3 and Figure 4 allow the user to first select the connector type and then the particular device. When a check standard is selected, *F7* displays the name of the database file chosen. For example, if the Type N 3 dB attenuator is selected, *F7* would display DB File: N-40DB85.

See Section 5 for the file naming convention.

3.3.8. *F8*: MAIN MENU

This softkey returns the user to the Main Menu.



```
2 Apr 1996                                                    11:32:02
                8753C CHECK STANDARD DATABASE/MEASUREMENT PROGRAM
                      Version:A0 [3.48] November 2, 1995

                                    HP8753  TYPE N
Male 10 dB+Short @ Port 1     Model No. 44-10/Short Serial No. AS9616
 FREQ.  No.of  Mean Mag.  Std. Dev.   Mean Phase  Std. Dev.
 (MHz)  Meas.  (linear)                  (deg)      (deg)
    .3     1   0.122041   0.000000    179.922     0.000
   1.0     5   0.122028   0.000015    179.771      .004
   5.0     1   0.121951   0.000000    178.912     0.000
  10.0    17   0.121906   0.000034    177.871      .007
  14.0     1   0.121863   0.000000    177.041     0.000
  20.0     4   0.121796   0.000065    175.815      .005
  24.0     1   0.121695   0.000000    175.014     0.000
  30.0     4   0.121678   0.000055    173.766      .011
  40.0     4   0.121569   0.000071    171.713      .015
  50.0    19   0.121498   0.000041    169.685      .008
  60.0     4   0.121385   0.000054    167.657      .012
  70.0     5   0.121294   0.000065    165.632      .006
  80.0     4   0.121203   0.000050    163.596      .024
  90.0     4   0.121099   0.000069    161.568      .010
 100.0    19   0.121007   0.000039    159.545      .008
 110.0     1   0.120984   0.000000    157.522     0.000
 120.0     1   0.120862   0.000000    155.523     0.000
 130.0     1   0.120766   0.000000    153.501     0.000

Displayed 18 of 82 frequencies. Press any key to continue
```

Figure 22. Example of a display from a summary file (SUM) for a Type N 1-port check standard. At each frequency, the number of measurements, the mean, and the standard deviation of the pertinent parameters are listed. Here, the linear magnitude and phase angle are displayed. For a 2-port device, usually an attenuator, the magnitude and standard deviation in dB are displayed.

3.4. EDIT DATABASE MENU

The Edit Database Menu allows the user full control over the contents of the two database files for each check standard. These two files are called the database file (DBF extension) and the summary file (SUM extension). This menu allows the user to delete records from or add records to the DBF file. In the latter case, the data is extracted from the CD files which are saved separately. In principle, a database file may be completely reconstructed from the CD files if it is accidentally deleted or corrupted. The display for this menu is shown in Figure 23. The labeled softkeys are defined below.

3.4.1. *F2*: Delete Record

Records in the database (DBF) file may be deleted by selecting this item. When this item is selected the following message is displayed:

```
You must know what record you want to delete. If you're not sure, please
return to the View Menu and select Display DBF File.

Do you wish to continue? (Y/N)
```

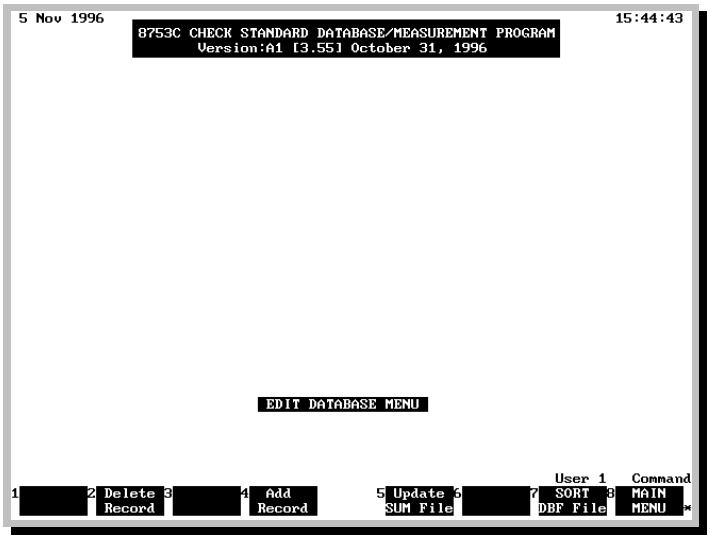


Figure 23. The Edit Database Menu display. This menu allows the user to delete or add records to a selected database file or to update a SUM file.

If the user selects Yes (Y), the program requests the user to select a connector type and check standard device (see Figures 3 and 4). Next, the program asks for the record number that will be deleted. If a valid number is entered (it must be a number and be within the range of records in the selected database file), the program proceeds to delete the selected record from the database. The user may enter 0 for the record number to exit without deleting any records from the database. The database summary file (SUM) is updated next to reflect the change made in the database. The old database file (only the DBF file) is stored with the file name extension BAK.

3.4.2. *F4*: Add Record

This item allows the user to add records to a database using the data stored in the CD files. When this softkey is selected, the program requests the user to select a connector type and check standard device (see Figures 3 and 4). After this selection, a list of CD files for the specified check standard device is displayed. The user selects the desired CD file by highlighting the file and pressing the *Enter* key. The program reads the selected CD file and appends the appropriate data to the database (DBF) file. The database summary file (SUM) is updated to reflect the changes in the database. As with the Delete Record selection, the old database (DBF) file is stored with the file name extension BAK.

See Figure 5 for an example of the CD file list.

3.4.3. *F5*: Update SUM File

The summary file contains the current values of the number of measurements, mean, and standard deviation at each measurement frequency for each check standard. This softkey directs the program to read each record of the database (DBF) file and use this information to "update" the number of measurements, mean, and standard deviation at each frequency. The user would select this operation if it was suspected that the summary file had not been properly updated or if the user had deleted a record from the DBF file using a DOS text editor and not this program.

When this item is selected, the program requests the connector type and check standard device (see Figures 3 and 4) and then proceeds to update the selected summary file without any further warning. When the operation is completed, the program returns to the Edit Database Menu.

3.4.4. *F7:* SORT DB File

Because the program allows the user the capability to add data to the database from a stored CD file, the records within the database could be stored out of date sequence. This selection allows the user to sort the records in a selected check standard database by date - from the earliest to the latest date. When this softkey is selected, the program requests the connector type and check standard device (see Figures 3 and 4) and then begins the sorting process. The status of the process is shown on the screen and, when completed, the following message is displayed:

```
The records if file N_3DB87.DBF have been sorted.
This new order can be stored in the file if you wish. The program will
make the old version a backup file with extension BAK.

Do you wish to store the SORTED records in file N_3DB87.DBF? (Y/N)
```

Selecting No (N) returns the user to the Edit Menu. Selecting Yes (Y) stores the sorted records in the indicated DBF file and returns to the Edit Menu.

3.4.5. *F8*: MAIN MENU

This softkey returns the user to the Main Menu.

3.5. COPY MENU

The Copy Menu is the softkey menu displayed when data has been plotted. The softkeys have different definitions depending on the type of check standard and the operation selected. Table 1 summarizes the softkey

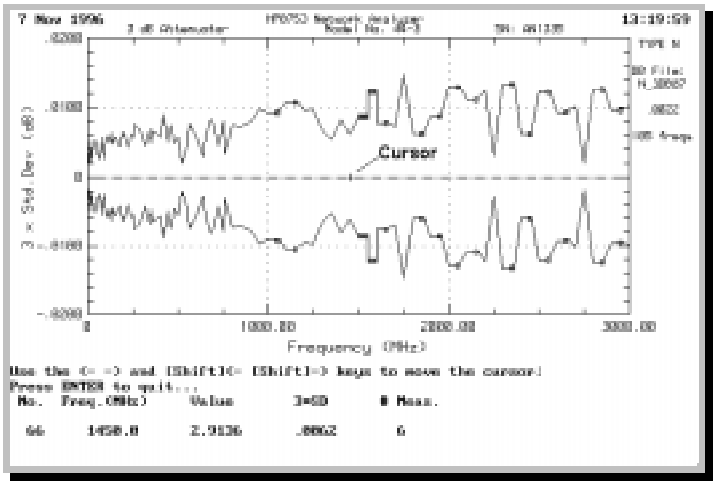


Figure 24. Example of the display when softkey *F3* is selected. A cursor (indicated in the figure) appears at a data point. The user moves the cursor with the left or right arrow keys. The display shown below the plot shows the frequency number in the database, the frequency (in MHz), the value measured at that frequency, three times the calculated standard deviation, and the number of measurements for the cursor or cross-hair location.

displays for each softkey as a function of the plot type. The functions associated with softkeys *F1*, *F2*, *F4*, *F7*, and *F8* have been described in previous sections. The functions of the remaining softkeys are described below.

3.5.1. *3*: Digitize Point

For any type of plot, when the Digitize Point softkey *F3* is selected, a display similar to that shown in Figure 24 is exhibited. A cursor or cross-hair is displayed and the frequency and measured value are shown immediately below the plot. The user may move through the data to observe the variation in the calculated standard deviation and the number of measurements at each frequency. In Figure 24, only the uncertainties are plotted. In this case, the cursor remains at the zero line. For other plots, the cursor will move to the measured mean value. When a date and the summary data are plotted, the cursor shows the mean values in the database and not the values of the individual plotted points. However, for a time history plot, the values at the individual points are displayed.

Table 1. Summary of the softkey definitions in the Copy Menu. Many of the definitions change depending on what type of plot is presented.

		Check Standard Device		
Softkey	Plot Type	Attenuator	1-port	Figure Examples
F1	New Measurement	Not Defined	DisplayMag OR Display Phase	8a, 8b
	Summary	Not Defined	DisplayMag OR Display Phase	11, 12, 13, 14, 15, 16
	Date & Sum.	Not Defined	DisplayMag OR Display Phase	17
	Time History	Not Defined	DisplayMag OR Display Phase	18, 19
F2[1]	Time History	Plot Meas. Date OR Plot Meas. No.	Plot Meas. Date OR Plot Meas. No.	18, 19
F3	ALL	Digitize Point	Digitize Point	8a, 8b, 11, 12, 13, 14, 15, 16, 17, 18, 19
F4	New Measurement	Display Unc. Only OR Display Val. & Unc.	Display Unc. Only OR Display Val. & Unc.	8a, 8b
	Summary	Display Unc. Only OR Display Val. & Unc.	Display Unc. Only OR Display Val. & Unc.	11, 12, 13, 14, 15, 16
	Date & Sum.	Display Unc. Only OR Display Val. & Unc.	Display Unc. Only OR Display Val. & Unc.	17
	Time History	Display Unc. Only OR Display Val. & Unc.	Display Unc. Only OR Display Val. & Unc.	18, 19
F5	ALL	Dump Plot	Dump Plot	8a, 8b, 11, 12, 13, 14, 15, 16, 17, 18, 19
F6	ALL	Plotter: DeskJet	Plotter: DeskJet	8a, 8b, 11, 12, 13, 14, 15, 16, 17, 18, 19
F7[2]	New Measurement	Store New Data	Store New Data	8a, 8b
F8	New Measurement	Meas. Menu OR View Menu	Meas. Menu OR View Menu	8a, 8b
	Summary	View Menu	View Menu	11, 12, 13, 14, 15, 16
	Date & Sum.	View Menu	View Menu	17
	Time History	View Menu	View Menu	18, 19

Note 1: *F2* not defined for other Plot Types.
Note 2: *F7* not defined for other Plot Types.

3.5.2. *F5* Dump Plot

Selecting this softkey produces a printed copy of the plot on the plotter device defined by softkey *F6*. The program turns off the softkey display prior to the dump so that the softkey menu is not printed with the plot.

3.5.3. *F6* Plotter: DeskJet

Selecting this softkey steps through the list of plotting devices defined in the program. The plotting device displayed here is the one on which the plot will be printed (or plotted as the case may be) when the Dump Plot softkey (*F5*) is selected.

4. SUBPROGRAMS

The Check Standards and Database programs employs 64 subprograms or functions to carry out its operations. All these subprograms and functions are summarized in Table 2 and listed according to their major function. In addition to the subprograms, there is a Main context which contains a variety of information regarding the database file structure and subprograms. The Main context calls the subprogram Csp_vana (described below) when the program is run in the standalone mode. This section describes the function of some selected subprograms and functions.

4.1. Main Subprogram

The main subprogram in the program is Csp_vana. This subprogram contains all the various menus and the subroutines used to call the necessary subprograms and functions.

4.2. VANA I/O

The set of subprograms that perform operations associated with the network analyzers are summarized under this heading. The function of these subprograms is described below.

4.2.1. Acq_data

The S-parameter data from the network analyzer is acquired by this subprogram. The calling subprogram, which is Csp_vana, defines the specific S-parameter measurements (either S_{11}, S_{22}, or S_{21} - depending on the type of check standard measured) that are acquired.

Table 2. List of all subprograms and functions in the Check Standards and Database program ordered by major function.

Main Subprogram	Database Operations	General Plotting
Csp_vana	Add_record	Plot_lib
	Rw_data_file	Plot
VANA I/O	Rw_sum_file	Axis_div
Acq_data	Update_sum_data	Label
Find_freqs	Dbf_rec_array	Csize
Select_std	Update_sum_file	Ldir
Sel_con_type	Zero_freq	Lorg
Print_con_type	Zero_data	Line_type
Select_vana	Sort_dbf	Char_size
Setup_nwa	Branch	Num_label
Nwa_sweep	FNNum_recs	Draw_axes
	Del_record	Draw_rec
General Utilities	FNCheck_rec	Draw_x_axis
FNHgl$	Read_def	Draw_y_axis
FNMonth$	FNCheck_sel	
Key_pressed		**Misc**
Box	**Data Plotting**	Help_display
Disp_time	Plot_cd_data	
Disp_menu	Setup_plot_par	
Clear_screen	Plot_info	
Disp_heading	Plot_rel_unc	
FNLast_disp_line	Plot_time_hist	
	Digi_point	
File Utilities	Disp_params	
Sel_path		
Catfiles		
Disp_cdfile		
FNIndex		
Read_cd_file		
FNPath$		
FNDbf_name$		
Protect_file		
FNDefine_cd$		

4.2.2. Find_freqs

The dimension statements for the data and frequency array variables are located in Csp_vana.

Prior to acquiring measurement data, the program calls this subprogram to obtain the list of frequencies at which the network analyzer has been calibrated. Currently, the maximum number of frequencies allowed is 401, but this number may be changed by editing the dimension statements for the frequency and data array variables.

4.2.3. Setup_nwa

This subprogram checks first of all for the presence of an IEEE-488 interface. If the interface is not found (which of course also means that no network analyzer can be accessed) then the following error message is displayed:

```
An HP-IB card is not present!

Database files may be accessed but no new measurements are allowed.

Press any key to continue...
```

If an HP-IB interface is present, a check for the presence of a network analyzer is made. If one is detected, a few setup operations are done to the network analyzer. If no network analyzer is detected, then the following message is displayed:

```
The Network Analyzer is not responding!
Check that it is turned on or that the proper HP-IB cable is connected.

Database files may be accessed but no new measurements are allowed.

Press any key to continue...
```

See Figure 1 for an example of the Definition File list display. If only one Definition file exists, it is automatically opened and read and no Definition file list is displayed.

When either of the above messages are displayed, the list of definition files is displayed allowing the user to select the desired file from the list.

This subprogram also checks whether an instrument at the designated IEEE-488 address (the default address is 716, but this may be changed by the user) is one of the permitted network analyzer models. If not, then the message below is displayed and the program stops or returns to the original calling program.

```
Unknown Network Analyzer model (not an HP8753 or HP8510)!

Database files may be accessed but no new measurements are allowed.

Press any key to continue...
```

4.2.4. Nwa_sweep

In subprogram Csp_vana, prior to data acquisition, this subprogram is called to force the network analyzer to perform a measurement restart and update the measurement data at the listed frequencies.

4.3. General Utilities

The subprograms and functions listed under this heading are called by many other subprograms to modify the CRT display and capture keyboard input. The function of each of these subprograms or functions is described below.

FNHgl$	Highlights the passed string.
FNMonth$	Returns the month number (e.g. SEP=09).
Key_pressed	Returns the key pressed and, optionally, displays the time.
Box	Draws an open or filled box of size defined by passed values.
Disp_time	Displays the time at a specified location.
Disp_menu	Displays a highlighted menu name at the bottom of the CRT print area.
Clear_screen	Clears the crt between the defined lines.
Disp_heading	Displays the program heading.
FNLast_disp_line	Returns the last line in the display area.

4.4. File Utilities

The subprograms and functions listed here are related to file input and output. Some functions define the database file path while others define the name of the appropriate file. The file paths and names are constructed from information obtained from the DEF file.

4.4.1. Sel_path

This subprogram defines the DOS path for Control Data files. The subprogram takes the drive and directory for the database files defined by the definition file and appends the subdirectory named CD_FILES to this path.

4.4.2. Disp_cdfile/Read_cd_file

The subprogram Disp_cdfile displays the information contained in a previously stored ASCII check standard (or control device) file. The user is asked for the connector type and standard; the subprogram then lists the

files that fit those values. Read_cd_file is called by Disp_cdfile to open, read, and display the contents of the selected CD file.

4.4.3. FNPath$

FNPath$ is a string function that returns the file name and directory path in the proper format for either LIF, HPW, or DFS. The path passed to this function must have the form valid for HP BASIC, i.e. *:DOS,A* for the A drive on the PC. The function accounts for the format differences between HP BASIC and HTBasic as well.

4.4.4. FNDbf_name$/FNDefine_cd$

String function FNDbf_name$ returns the proper DBF file name based on the connector type, check standard device, and the network analyzer model. The string function FNDefine_cd$ returns the prefix of the CD file based upon the connector type, standard type, and test set port.

4.4.5. Protect_file

This subprogram sets or unsets the RW attribute of all the database files in the selected network analyzer directory.

4.4.6. Catfiles

This subprogram displays a listing of selected files within a specified directory. The user can move through the list and select the desired file. This subprogram is used to display the list of definition files (see Figure 1) or the list of CD files (see Figure 5) for a selected connector type and check standard device.

4.5. Data and General Plotting

The subprograms listed under this heading are used to plot the data in the various formats described previously. The general plotting subprograms are not specific to the check standard program but can be used to plot many different types of graphs.

4.5.1. Plot_cd_data

Plots the mean values from the SUM file and, if applicable, newly acquired data or a selected record from the DBF file.

4.5.2. Setup_plot_par/Disp_params

Subprogram Setup_plot_par sets up the Plot Parameters based on the connector type, device, and NWA. The Plot Parameters are the X-axis and Y-axis limits (only for phase displays; Y-axis limits for the magnitude displays are found in the subprogram Plot_cd_data). The subprogram Disp_params allows the user to change the x- and y-axis limits on frequency plots. The user has no control over x- and y-axis limits for time history plots.

4.5.3. Plot_info

Displays information about a currently displayed plot.

4.5.4. Plot_rel_unc

Plots the relative uncertainty from the SUM file and, if applicable, newly acquired data or a single record from the DBF file.

4.5.5. Plot_time_hist

The time history for data at a selected frequency are plotted by this subprogram. The data at the selected frequency are found from the DBF file in subprogram Csp_vana.

4.5.6. Digi_point

Subprogram Digi_point allows the user to move through the displayed plot to view information at each frequency. Calling the subprogram produces a cross-hair display on the current plot. The user presses the left and right arrow keys to move the cross hair. The screen shows the frequency, mean, standard deviation, and number of samples at the cross hair position.

4.6. Database Operations

The set of subprograms and functions listed under this heading are the heart of the check standard program. They provide the capability to add or delete records, update the database/summary files, read the definition file, and read from and store data to the DBF and SUM files.

4.6.1. Add_record

This subprogram adds the data from a previously stored Control Data (CD) file to the database. The user selects the appropriate CD file according to

the connector type and the check standard device. The data is stored as a new record in the DBF file and the mean and standard deviation are updated in the SUM file.

4.6.2. Del_record

Subprogram Del_record allows the user to delete a record from the database. The record is selected according to record number. If the user does not know the record number, the subprogram allows the contents of the DBF file to be displayed in the same manner as softkey *F5* (Display DBF File) from the View Menu. When a record is deleted, the subprogram renames the old DBF file with the BAK extension and copies all data records, except for the deleted record, to a new file. The SUM file is then updated by calling the subprogram Update_sum_file.

4.6.3. Rw_data_file

The subprogram reads and writes data to the appropriate DBF file selected by the user according to the connector type and the check standard device.

4.6.4. Rw_sum_file

The subprogram reads and writes data to the appropriate SUM file selected by the user according to the connector type and the check standard device.

4.6.5. Read_def

Subprogram Read_def reads the data from the selected DEF file to define the check standard and file names.

4.6.6. Update_sum_file

This subprogram reads each record in the DBF file to recalculate the mean and standard deviation which is then saved in the SUM file. Update_sum_file should be used if the user suspects that the data in the SUM file has been corrupted or when the user has deleted a record from the DBF file using a text editor.

4.6.7. Update_sum_data

Subprogram Update_sum_data is called by Update_sum_file when a database file must be updated. This subprogram calculates the means and standard deviations for the data.

4.6.8. Dbf_rec_array

This subprogram is called by softkey *F5* (Display DBF File) from the View Menu. The subprogram reads each record of the DBF file and prepares a string array which is then displayed on the screen.

4.6.9. Sort_dbf

This subprogram sorts the records in the DBF file by the date stored in each record. The newly sorted data is then saved in the DBF file. No updating of the means or standard deviation is done or required.

5. PROGRAM FILES

The check standard program requires several different types of files. All the files, except for the definition (DEF) files, are created by the program. Each of the files is a DOS text file so that the user may use a text editor to view the contents of the file, edit the file, or import the file into other programs such as spreadsheet programs. Of course, editing any of the files created by the program should only be done if the user fully understands how the changes may affect the operation of the program with those files.

The check standard program uses five types of files in its operation. The definition or DEF file is created by the user and must conform to the format described in the section below and the appendix. The database or DBF file contains the measured check standard data as separate records in the file. The summary or SUM file contains the calculated mean and standard deviation for each frequency that appears within the corresponding DBF file. The control data or CD files are separate files that contain measurements for a specific check standard. Finally, the help file contains the information that is displayed when the user presses Alt-H. Each of these files is discussed in the next sections and the format requirements and examples of the files are provided in the Appendix.

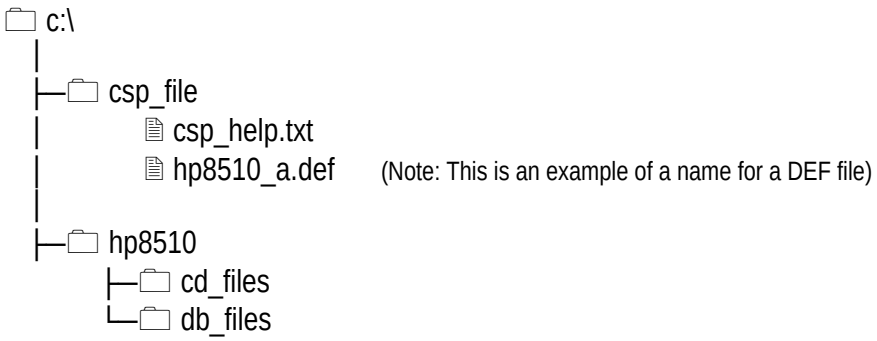
5.1. File Requirements

The program requires the presence of a subdirectory named CSP_FILE on the drive that is defined at the beginning of subprogram Csp_vana. The drive letter is defined by the statement `Drive$="C"` for the C hard drive. Any drive letter that is available to the computer (floppy or network drives) may be used. Within the CSP_FILE directory, at least one DEF file and the help file named CSP_HELP.TXT are required.

The DEF file defines the drive and the database directory names. If the DEF file defines a drive different from the default drive defined within the

program, this new drive must also have a subdirectory named CSP_FILE with at least one DEF file and the help file.

The database files (those having the file extensions DBF and SUM and the CD files) are stored in subdirectories DB_FILES and CD_FILES in the directory defined by the DEF file. For example, assume that the database files reside on the C drive of the computer and that the DEF file defines HP8510 as the name of the database directory. Then the directory structure and required files would be:



The file storage requirements depend on the number of check standards that are used and the rate of measurements. For example, the Microwave Project in the Sandia Primary Standards Laboratory uses twenty check standard devices in four connector types. For the HP8510 Network Analyzer, there are 79 files in the DB_FILES directory using 667 kB of disc space and 629 files in the CD_FILES directory using 1.10 MB of space. On average, the size of the CD files is small; they are typically of the order of 2 kB. The DBF files vary in size depending on the number of records and the number of frequencies in the file. Presently, the largest DBF file is 27 kB.

5.2. File Types

Each of the five file types used by the check standard program are described in the following sections. The user may also refer to the appendices for specific format requirements and examples of the files.

5.2.1. DEF Files

The definition files having the extension DEF are required by the program to define the drive and the directory names that contain the database files. In addition, the DEF file contains the number and names of the types of

connectors and the check standard devices. This information is used by the program to create the names of the various files required by the program. Once these file names have been defined within a particular DEF file. the user is no longer required to remember the names or the naming convention that is used. The software will handle these details. The format for the DEF files and an example of a definition file is shown in Appendix C.

5.2.2. DBF Files

In the database file, which has the extension DBF, each line is a separate record containing a set of measurements of the specified device. The length of the line varies depending on the type of device (attenuator or mismatch) and the number of measurement frequencies. Each record contains the measurement date and time, the number of frequencies, and the value of the measured parameter at each frequency. For attenuators only, the transmission magnitude (specifically, the magnitude of the S_{21} scattering parameter) in units of dB is stored. For the one port devices, both the reflection magnitude and phase (for either the S_{11} or S_{22} scattering parameter) are stored at each measurement frequency. Appendix D describes the format of the DBF file for each type of device.

This file is prepared by the check standard program. Since it is a DOS text file, it may be viewed using any text editor. However, the user is cautioned not to edit the file since a change in the file's format may prevent the program from correctly reading the data within the file. The user may elect to delete a record in the file using an editor rather than using the check standard program. If this is done, then the user must update the summary file from the Edit Menu of the program.

The program sets the file attribute of the DBF and SUM files to read-only when the program is exited (from the Main Menu). This is done to prevent inadvertent editing or deleting of any of the files. The user may modify the files by resetting the attribute.

5.2.3. SUM Files

The summary files use the file extension SUM and have a much different structure than the DBF files. The SUM files contain the calculated mean and standard deviation values and the number of measurements at each frequency. Separate lines are used to store magnitude and phase data for the check standard if applicable. All data is stored with the same precision as the number is stored in the computer. Appendix E describes the format of the SUM file and also shows an example of data in the file.

The DBF and SUM files exist as related pairs of files. Each DBF file has a corresponding SUM file. The file names are identical except for the file extension. For example, for a Type N 3 dB attenuator check standard, the file names of the DBF and SUM files could be N_3DB85.DBF and N_3DB85.SUM, respectively.

The SUM files are completely prepared by the check standard program. The same cautions should be exercised by the user as with the DBF files when the SUM files are viewed or edited by a text editor. If data is deleted from this file, the file will not accurately reflect the contents of the corresponding DBF file. If the file is accidentally changed and cannot be restored, then the user should update the file from the Edit Menu.

5.2.4. CD Files

The control data or CD files contain the measurement data from a specific check standard obtained on a particular date and time. The first two letters of the file name refer to the connector type and the check standard device. The next six characters are the date of the measurement. The first two characters of the file extension refer to the measurement system and the last character is a count of the number of files for that check standard stored on that particular day. For example, for the Type N 3 dB check standard measured on the HP8753 Network Analyzer on January 2, 1997, the CD File name might be 23010297.870. If the check standard is measured again on that day and the data is stored, then the file name would be 23010297.871. These files are stored in the CD_FILES subdirectory as described above.

The CD files are a form of backup for the database files. If the user accidentally deletes the wrong record from the DBF file, that record may be added from the Edit Menu by selecting the correct CD file. (This assumes that the user at least had an idea of the measurement date for the deleted data.) Examples of CD files are provided in Appendix F.

The contents of the CD files may be viewed from the Main Menu.

Again, these files are prepared by the program and so the user should be careful when viewing these files with a text editor**. The CD files should not be changed by the user!** If the files are modified there is no way to restore them to their unaltered state.

5.2.5. Help File

In the various menus of the check standard program. the user may obtain more information on the functions of the softkeys by pressing Alt-H. This brings up a help display whose contents are stored in the CSP_HELP.TXT file in the CSP_FILE directory.

The help file, CSP_HELP.TXT, is a DOS text file. The first line of the file is a header line with information about the last revision. The next line defines the help page number. Within the check standard program, each menu or special view is given a separate help page number. When Alt-H is pressed, the program uses this number to select the text to display from CSP_HELP.TXT. The next eight lines in the file provide information on the softkeys or other advice for the displayed screen. The program only displays eight lines of text from the help file. An example of part of the contents of CSP_HELP.TXT are shown below in Table 3. An example of how the help display appears on the CRT screen is shown in Figure 25.

Table 3. Example of part of the contents of the help file CSP_HELP.TXT.

```
CSP_VANA HELP FILE VERSION A0.02:07/30/96
HELP PAGE #1  MAIN MENU
F1:  Go to the Measurement Menu
F2:  Change the drive containing the Database Files
F3:  Select a new Definition (.DEF) File
F4:  Display measurement data from a Control Data File
F5:  Go to the View Menu
F6:  Go to the Edit Menu
F7:  Pause the Program
F8:  Exit the Program
HELP PAGE #2  VIEW MENU
F1:  Plots all the data from the selected Summary (.SUM) File
F2:  Plots all data from the Summary File with data from a specific date
F3:  Plots all data for a specified frequency
F4:  Go to the Plot Setup Menu
F5:  Displays individual records in the Database (.DBF) File
F6:  Displays the mean & standard deviation for all measured frequencies
F7:  Selects the Check Standard
F8:  Returns to the Main Menu
```

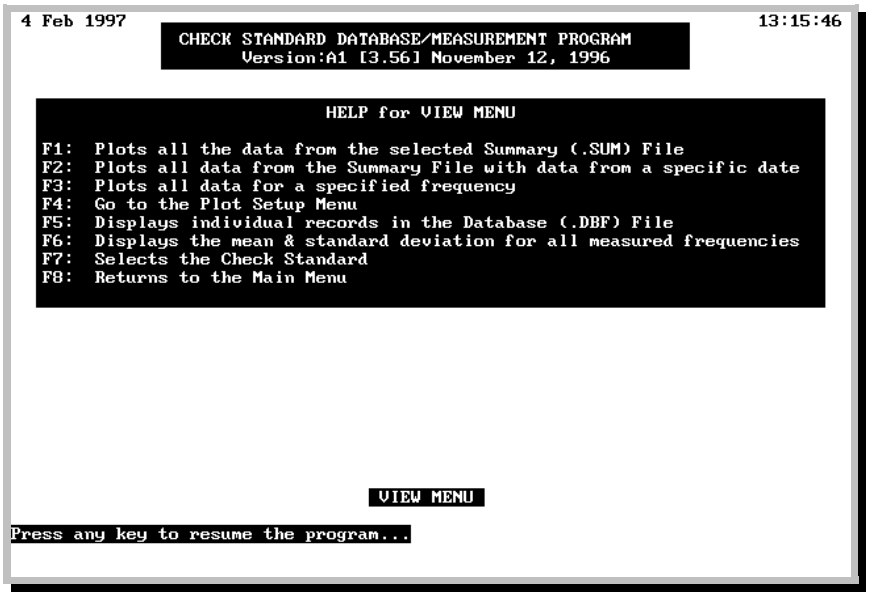


Figure 25. Example of the Help Display obtained by pressing Alt-H.

6. REFERENCES

1. L. E. Duda, “Vector Network Analyzer Check Standards Measurements and Database Software,” Proceedings 47th ARFTG Conference, June 1996.

2. L. E. Duda, “Check Standard Measurement and Database Software for Microwave Network Analyzers”, Proceedings 1997 Measurement Science Conference, January 23-24, 1997, Pasadena, CA.

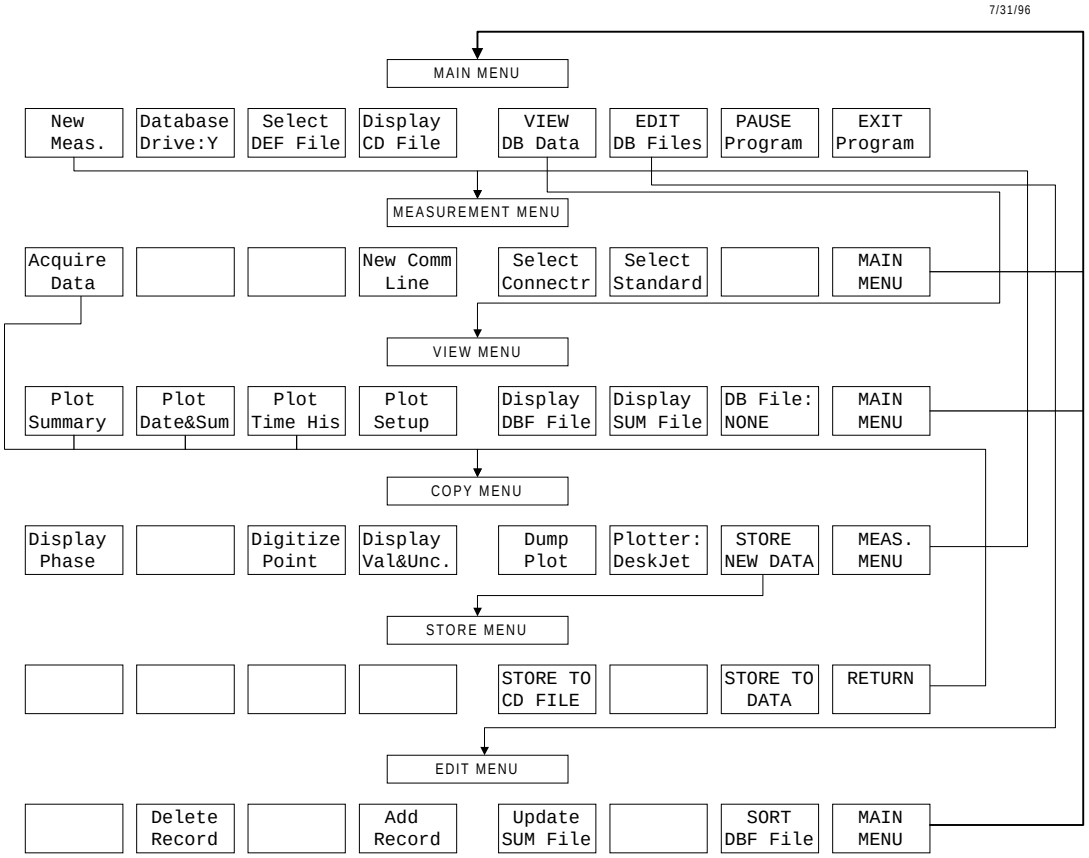
3. C. Croarkin, “Measurement Assurance Programs Part II: Development and Implementation,” NBS Special Publication 676-II, April 1984.

4. Reference to a commercial product is included for completeness only and implies neither endorsement by Sandia National Laboratories or the Department of Energy nor lack of a suitable substitute.

5. D. C. Montgomery and G. C. Runger, Applied Statistics and Probability for Engineers, John Wiley & Sons, Inc., New York, 1994.

APPENDIX A

MENU FLOW CHART



APPENDIX B

CALCULATION OF THE STANDARD DEVIATION

The following derives an expression to calculate a "running" standard deviation within the CSP_VANA program. The variance (that is, the square of the standard deviation) is given by

$$s^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1} \tag{B-1}$$

where the mean value is given by

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}, \text{ and } \qquad \bar{x}^2 = \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n^2}. \tag{B-2}$$

Expanding the term in parenthesis in B-1 and using the definition of the mean value in B-2, the variance from B-1 may be written as

$$s^2 = \frac{1}{n-1}\left[\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n}\right]. \tag{B-3}$$

Rewriting the expression in B-3 by placing over a common denominator and defining the "full" (for all n data points) variance as ${}^{n}s^2$, equation B-3 becomes

$${}^{n}s^2 = \frac{\sum_{i=1}^{n} x_i^2}{n-1} - \frac{n\left(\frac{\sum_{i=1}^{n} x_i}{n}\right)^2}{n-1} = \frac{\sum_{i=1}^{n} x_i^2}{n-1} - \frac{n\left({}^{n}\bar{x}\right)^2}{n-1}. \tag{B-4}$$

where ${}^{n}\bar{x}$ is the mean value which includes all n data points. If the nth point is pulled out of the summation from the first term in B-4, then

$${}^{n}s^2 = \frac{\sum_{i=1}^{n-1} x_i^2 + x_n^2}{n-1} - \frac{(n-1)\left({}^{n-1}\bar{x}\right)^2}{(n-2)}\left(\frac{n-2}{n-1}\right) + \frac{(n-1)\left({}^{n-1}\bar{x}\right)^2}{(n-2)}\left(\frac{n-2}{n-1}\right) - \frac{n\left({}^{n}\bar{x}\right)^2}{(n-1)} \tag{B-5}$$

where the two middle terms are the same - they have been added and subtracted to allow a subsequent comparison. Expanding terms in equation B-5 gives

APPENDIX B

$$ {}^{n}s^{2} = \frac{\sum_{i=1}^{n-1} x_i^2}{n-2}\left(\frac{n-2}{n-1}\right) - \frac{(n-1)\left({}^{n-1}\bar{x}\right)^2}{(n-2)}\left(\frac{n-2}{n-1}\right) + \frac{x_n^2}{(n-1)} + \left({}^{n-1}\bar{x}\right)^2 - \frac{n\left({}^{n}\bar{x}\right)^2}{(n-1)}. \qquad \text{(B-6)} $$

Collecting similar terms yields

$$ {}^{n}s^{2} = \left[\frac{\sum_{i=1}^{n-1} x_i^2}{n-2} - \frac{(n-1)\left({}^{n-1}\bar{x}\right)^2}{(n-2)}\right]\left(\frac{n-2}{n-1}\right) + \frac{x_n^2}{(n-1)} + \left({}^{n-1}\bar{x}\right)^2 - \frac{n\left({}^{n}\bar{x}\right)^2}{(n-1)}. \qquad \text{(B-7)} $$

Comparing the term in the brackets in equation B-7 with equation B-4, allows B-7 to be rewritten in the following form

$$ {}^{n}s^{2} = \left({}^{n-1}s^{2}\right)\left(\frac{n-2}{n-1}\right) + \frac{x_n^2}{n-1} + \left({}^{n-1}\bar{x}\right)^2 - \left({}^{n}\bar{x}\right)^2\left(\frac{n}{n-1}\right) \qquad \text{(B-8)} $$

This expression states that the new standard deviation, for the nth data point, may be found from the prior standard deviation, the prior mean value, and the new mean value. This algorithm is incorporated into CSP_VANA to allow calculations of new standard deviations without the need to recalculate all previous data. The only requirement is that the database files must store the calculated mean, standard deviation, and number of data samples for each frequency.

APPENDIX C

DEFINITION FILE (DEF) STRUCTURE

Line	Description	Variable Name	Type	Size	Example
1	Version #	Version$	Str	80	CSP_VANA DEF FILE Vers. A1
2	Directory Name	Dir$	Str	8	HP8753
3	Drive letter	Drive$	Str	1	C, D, Y, etc.
4	Measurement System abbreviation	Ms_abb$	Str	2	87
5	Number of Connector Types	No_conn	INT	-	4
Loop over number of connector types					
6	Connector Type #	Conn_no	INT	-	1
6	Connector Name	Conn_type$(Conn_no)	Str	10	APC-7 mm
6	Connector abbreviation	Con_abb$(Conn_no)	Str	2	7_
7	Number of Check Stds for connector	No_cs(Conn_no)	INT	-	4
Loop over number of check standards					
8	Check Standard Index	Setup(No_cs(Conn_no),1)	INT	-	1
8	Test Set Port Number	Setup(No_cs(Conn_no),2)	INT	-	0
8	Phase Display Flag	Setup(No_cs(Conn_no),3)	INT	-	0
9	Check Standard label	Std_lbl$(Conn_no, No_cs())	Str	80	10 dB Atten. + Short @ Port 1...
10	Check Standard abbreviation	Std_abb$(Conn_no,No_cs())	Str	8	P1-A
11	CD File prefix	Cdf_pref$(Conn_no,No_cs())	Str	2	1A

NOTE: Type refers either to a string (Str) or an integer (INT) variable. Size is the number of characters. Variables that are listed on the same line on the same line are comma delimited.

The number of lines may be found from:

$$Number\ of\ Lines = 5 + No\_conn \cdot 2 + \sum_{i=1}^{No\_conn} 4 \cdot No\_cs(i)$$

For the example shown on the following pages,

Number of Lines = 5+4*2+[4*4+4*6+4*6+4*4] = 93 lines.

APPENDIX C

DEFINITION FILE EXAMPLE

The following table is an example of the contents of a typical DEF file. In this case, it is for the HP8753 Network Analyzer. Four connector types are listed with either four or six check standards for each connector type.

Line No.	Contents
1	Version A0
2	HP8753
3	Y
4	87
5	4
6	1,APC-7 mm,7_
7	4
8	1,1,1
9	10 dB Atten.+Short @ Port 1 Model No. 8492A/Short Serial No. 202330
10	P1-A
11	1A
12	2,2,1
13	10 dB Atten.+Short @ Port 2 Model No. 8492A/Short Serial No. 202330
14	P2-B
15	1B
16	3,3,0
17	3 dB Attenuator Model No. 17-3 Serial No. AN2859
18	3DB
19	13
20	4,3,0
21	40 dB Attenuator Model No. 17-40 Serial No. AM8927
22	40DB
23	14
24	2,TYPE N,N_
25	6
26	1,1,1
27	Male 10 dB+Short @ Port 1 Model No. 44-10/Short Serial No. AS9616
28	MP1A
29	2A
30	2,2,1
31	Female 10 dB+Short @ Port 2 Model No. 8491A/Short Serial No. 6842
32	FP2
33	22
34	3,3,0
35	3 dB Attenuator Model No. 44-3 Serial No. AN1335
36	3DB
37	23
38	4,3,0

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```
39      40 dB Attenuator          Model No. 44-40      Serial No. AN2805
40      40DB
41      24
42      5,2,1
43      Male 10 dB+Short @ Port 2    Model No. 44-10/Short Serial No. AS99616
44      MP2B
45      2B
46      6,1,1
47      Female 10 dB+Short @ Port 1  Model No. 8491A/Short Serial No. 6842
48      FP1
49      26
50      3,APC-3.5 mm,3_
51      6
52      1,1,1
53      Male 10 dB+Short @ Port 1    Model No. 8493C/Short  Serial No. 12629
54      MP1A
55      3A
56      2,2,1
57      Female 10 dB+Short @ Port 2  Model No. 8493C/Short  Serial No. 15325
58      FP2B
59      3B
60      3,3,0
61      3 dB Attenuator           Model No. 8493C      Serial No. 02024
62      3DB
63      33
64      4,3,0
65      40 dB Attenuator          Model No. 8493C      Serial No. 02556
66      40DB
67      34
68      5,2,1
69      Male 10 dB+Short @ Port 2    Model No. 8493C/Short  Serial No. 12619
70      MP2C
71      3C
72      6,1,1
73      Female 10 dB+Short @ Port 1  Model No. 8493C/Short  Serial No. 15325
74      FP1D
75      3D
76      4,GR-900,G_
77      4
78      1,1,1
79      Mismatch @ Port 1   Model No. 900-W100  Serial No. 419
80      MP1
81      41
82      2,2,1
83      Mismatch @ Port 2   Model No. 900-W100  Serial No. 419
84      MP2
```

85 42
86 3,3,0
87 6 dB Attenuator Model No. 900-G6 Serial No. 823
88 3DB
89 43
90 4,3,0
91 10 dB Attenuator Model No. 900-G100 Serial No. 1175
92 40DB
93 44

APPENDIX D

DATABASE FILE (DBF) STRUCTURE

The database file, having the DBF file extension, contains the measurement data for the specific check standard measured at a particular time. Each line is a separate record containing a set of measurements of the specified device. The length of the line varies depending on the type of device (attenuator or a one-port device) and the number of measurement frequencies.

For attenuators, each record contains:

Meas. date/time, Meas. Time, No_freqs, Freq(1), Atten(1),..., Freq(No_freqs), Atten(No_freqs)

using the image format:

IMAGE 17A,4D,No_freqs ∗ (6D.2D,3D.4D)

For one port devices, each record contains:

Meas. date/time, No_freqs, Freq(1), Mag(1), Phase(1),..., Freq(No_freqs), Mag(No_freqs), Phase(No_freqs)

using the image format:

IMAGE 17A,4D,No_freqs ∗ (6D.2D,D.6D,S3D.3D)

DBF FILE EXAMPLE

(from 3_3DB87.DBF)

NOTE: This is a truncated example of the database file. Each line represents a separate record in the database and it may extend to many more than the number of characters shown here.

```
 2 Feb 1994 08:14  41  1000.00  2.6629  1050.00  2.6607  1100.00  2.6667  1150.00  2.6653
 9 Feb 1994 12:24   6      .30  2.6378     5.00  2.6381    10.00  2.6390    50.00  2.6418
20 Dec 1993 12:03   9    10.00  2.6375    50.00  2.6425   100.00  2.6420   250.00  2.6473
 2 Jun 1994 08:53   7  1500.00  2.6682  1750.00  2.6723  2000.00  2.6816  2250.00  2.6784
28 Jul 1994 07:51  21  1000.00  2.6649  1050.00  2.6602  1100.00  2.6652  1150.00  2.6649
13 Jan 1995 11:59   9    10.00  2.6386    50.00  2.6406   100.00  2.6424   250.00  2.6509
 2 Feb 1995 14:28   5      .30  2.6385     5.00  2.6381    10.00  2.6393    50.00  2.6418
14 Mar 1995 09:09   8      .30 -2.6375     5.00 -2.6388    10.00 -2.6401    50.00 -2.6439
21 Mar 1995 09:11   2     1.00 -2.6389    10.00 -2.6422
 7 Jun 1995 13:54  32    10.00 -2.6379    50.00 -2.6415   100.00 -2.6432   200.00 -2.6458
 7 Jun 1995 14:02  32    10.00 -2.6386    50.00 -2.6418   100.00 -2.6435   200.00 -2.6465
 7 Jun 1995 14:09  32    10.00 -2.6393    50.00 -2.6426   100.00 -2.6425   200.00 -2.6473
```

APPENDIX E

SUMMARY FILE (SUM) STRUCTURE

These files have a much different structure than the DBF files. In the SUM files, all data is stored with the same precision as the number is stored in the computer. Separate lines are used for each type of measurement. The storage format is:

Line 1: No_std_freqs
Line 2: Std_freq(I), No_std_meas(I)
For 1-port devices:
Line 3: Sum_data(I,1,1),Sum_data(I,1,2),Sum_data(I,2,1),Sum_data(I,2,2)
or, for attenuators:
Line 3: Sum_data(I,3,1),Sum_data(I,3,2)

where I=1 to No_std_freqs. The total number of lines in the file is 2*No_std_freqs+1. Each value in a line is delimited by a comma.

SUM FILE EXAMPLE

(from 3_3DB87.SUM)

The example shown below is from the database file for a 3.5 mm 3 dB attenuator for the HP8753 Network Analyzer.

```
56
 .3, 3
 2.63791933333, .000531150954127
 1, 1
 2.638882, 0
 5, 3
 2.638345, .000424352448142
 10, 9
 2.63916988889, .00136986052615
 50, 8
 2.64204675, .000963215412341
 100, 8
 2.643385375, .00103899950918
 200, 3
 2.646522, .000757611378519
 250, 4
 2.64841125, .00188851959202
 300, 3
 2.64828233333, .000350785310933
 400, 3
 2.64812966667, .00105384075422
 500, 6
 2.65412816667, .00158771199135
```

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600, 3
2.65368766667, .000338506034048
700, 3
2.65679566667, .00108058564121
800, 3
2.65889333333, .000711629350764
900, 3
2.66086833333, .00189262419208
1000, 8
2.66422175, .00205969323339
1050, 2
2.66045, .000353553390147
1100, 5
2.6646098, .00138673075979
1150, 2
2.6651, .000282842711615
1200, 5
2.6677758, .00163806538238
1250, 2
2.66295, .00148492423972
1300, 5
2.6677142, .00181532950175
1350, 2
2.6654, .000989949494242
1400, 5
2.6710086, .0011794533899
1450, 2
2.66605, .000494974743981
1500, 8
2.67114825, .00154770454279
1550, 2
2.67055, .00134350288364
1600, 5
2.671476, .00117529762193
1650, 2
2.66975, .000353553390147
1700, 5
2.670827, .00129364717127
1750, 3
2.6686, .00369999999992
1800, 5
2.6753148, .000831867299023
1850, 2
2.67685, .00148492424151
1900, 5
2.678074, .00324613709004
1950, 2
2.67475, .00162634559684
2000, 8
2.678350875, .0023773747491
2050, 1
2.6785, 0
2100, 4
2.68086475, .00231747554621
2150, 1
2.6816, 0

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2200, 4
2.68103525, .00336363606529
2250, 2
2.6814, .004242640687
2300, 4
2.682299, .0014176645119
2350, 1
2.686, 0
2400, 4
2.6845375, .00211551073441
2450, 1
2.6828, 0
2500, 7
2.68499757143, .00354681683006
2550, 1
2.6919, 0
2600, 4
2.68485675, .00141587272897
2650, 1
2.6932, 0
2700, 4
2.687421, .00105482226018
2750, 2
2.68985, .00657609306521
2800, 4
2.68894475, .00230395100898
2850, 1
2.6923, 0
2900, 4
2.69147475, .00231217752713
2950, 1
2.6925, 0
3000, 5
2.6901766, .00202208575468

APPENDIX F

CONTROL DATA (CD) FILES

Two examples of the control data files are shown. The first shows the measurement data from a 3.5 mm 3 dB attenuator check standard. The second example shows data obtained from the measurement of a 3.5 mm one-port check standard measurement on port 2 of the network analyzer test set.

ATTENUATOR

```
8753C CONTROL DATA
Measurement Date: 14 Mar 1995     Time: 09:09:20
Connector Type: APC-3.5 mm
Standard: 3 dB Attenuator     Model No. 8493C   Serial No. 02024
Number of measurement frequencies:  8

Comment:
```

FREQ.	S11		S22		S21	
(MHz)	LIN Mag.	Angle	LIN Mag.	Angle	Mag.(dB)	Angle
.30	.005954	179.2859	.001829	.5328	-2.6375	-.0288
5.00	.005905	179.2131	.001885	1.7276	-2.6388	-.2225
10.00	.005910	178.6226	.001916	2.0750	-2.6401	-.4463
50.00	.005696	175.5917	.002080	6.4311	-2.6439	-2.2137
100.00	.005619	173.9658	.002286	13.5310	-2.6449	-4.4069
250.00	.005356	168.8379	.002709	7.9514	-2.6466	-10.9822
500.00	.005531	161.8684	.003789	-3.6612	-2.6546	-21.8957
1000.00	.006300	140.8887	.006138	-30.3181	-2.6685	-43.7132

APPENDIX F

ONE-PORT DEVICE

8753C CONTROL DATA
Measurement Date: 7 Jun 1995   Time: 14:01:11
Connector Type: APC-3.5 mm
Standard: Female 10 dB+Short @ Port 2 Model No. 8493C/Short Serial No. 15325
Number of measurement frequencies: 32

Comment:
Measurement #1.

FREQ. (MHz)	S22 LIN Mag.	Angle
10.00	.257137	179.1499
50.00	.256871	175.6563
100.00	.256694	171.3647
200.00	.256458	162.8517
300.00	.256025	154.3744
400.00	.255685	145.8614
500.00	.255066	137.3497
600.00	.254626	128.8064
700.00	.254120	120.2618
800.00	.253461	111.7241
900.00	.252866	103.1905
1000.00	.252163	94.6472
1100.00	.251463	86.0793
1200.00	.250709	77.5017
1300.00	.249975	68.9117
1400.00	.249186	60.2847
1500.00	.248467	51.6385
1600.00	.247732	42.9785
1700.00	.246928	34.2760
1800.00	.246245	25.5789
1900.00	.245645	16.8297
2000.00	.245104	8.0667
2100.00	.244665	-.7059
2200.00	.244168	-9.4716
2300.00	.243704	-18.2895
2400.00	.243548	-27.0827
2500.00	.243378	-35.8978
2600.00	.243322	-44.7185
2700.00	.243227	-53.4911
2800.00	.243410	-62.3543
2900.00	.243357	-71.1172
3000.00	.243576	-79.9489

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